

ANCIENT METAL TECHNOLOGY AND ARCHAEOLOGY OF SOUTH ASIA (A PAN-ASIAN PERSPECTIVE)



D.P. AGRAWAL



ANATOMY OF THE HINDU ARCHAEOLGY OF SOUTH ASIA

D. F. AGRAWAL

The focus of the book is primarily on the ancient metal technology of South Asia but its not a technical treatise. Archaeometallurgy has been situated in the matrix of archaeology. Such studies have a meaning only in the human context of the past. The Introductory chapter of the book emphasises, by giving examples, what such technical studies should aim at and what all one can glean about the past through them. The main emphasis is on copper/bronze but other metals have been duly covered: silver, gold, tin, arsenic, lead, brass and iron. As more detailed work is available now for the Indus Civilisation and its antecedent cultures, it has been discussed in two detailed chapters. But the other Chalcolithic cultures and the Copper Hoards have also been dealt with in adequate detail. The history of brass is quite polemical and it has therefore been given one full chapter. The chapter on iron summarises all the relevant issues but one could not go into all the details, as it requires a book to itself. The Central Himalayan region has been shown to be equally important for understanding the archaeometallurgy of South Asia. Linguistic evidence has been used to emphasise some of the new perspectives. Socio-economic implications of the archaeometallurgical evidence have been thoroughly discussed. The development of Indian metal technologies has been given in a global perspective but with a different bias. So far the emphasis has always been on West Asia. For the first time South Asian archaeometallurgy has been studied in the context of the eastern cultures of China, Thailand and Japan. The book gives an up-to-date summary of the recent archaeometallurgical evidence from China, Japan and Thailand. The problems to be addressed to in the future studies have also been highlighted.

All in all it is a book with a different perspective, written without using much technical jargon, tracing the evolution of metal technologies in an archaeological context. It is addressed to the general reader, but a specialist will also find adequate detail that one may need.

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**ANCIENT METAL TECHNOLOGY AND
ARCHAEOLOGY OF SOUTH ASIA
A Pan-Asian Perspective**

ANCIENT AND MEDICAL TECHNOLOGY AND
ARCHAEOLOGY OF SOUTH ASIA
A Two-Volume Project





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A Pan-Asian Perspective

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For friends who made it happen

Heather
Hideo
Vibha
Yoshinori

THE HINDU

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Received of the

THE HINDU

PREFACE

My work in Indian archaeometallurgy dates back to the seventies and eighties. A couple of years back I again got an opportunity to work in this field under a project sponsored by the Indian National Science Academy (INSA). This time it was not much of experimental analyses or fieldwork but more of research through published and unpublished sources. With my extensive contacts in the world of archaeology and archaeometallurgy, and full cooperation of friends, it was not very difficult to collect data or relevant literature. Following the old paradigms, earlier I too was looking towards West Asia for all cultural influences. But recently I got an assignment to visit Japan, which made me more aware of the Eastern world as well.

Despite my ignorance of their national languages, I tried to study the archaeometallurgy of Japan, China and Southeast Asia and found it equally if not more relevant to the study of the South Asian archaeometallurgy. My earlier visits to China and discussions with the Chinese archaeometallurgists in conferences both in Japan and China gave me valuable insights into the metal technologies of early China. Contacts with linguists like Professors. D. Bayard, R. Blust and L.A. Reid made me think of movements of early agricultural and metallurgical technologies through the Himalayan corridors, along with the movement of Austro-Asiatic languages. Dr. Ken Sasaki allowed me the use of his unpublished thesis on archaeometallurgy of Japan.

In this new perspective, our recent fieldwork and researches in the Central Himalayas also seemed to make more sense.

A consequence of all these new exposures and exercises was that I felt it was time to present South Asian archaeometallurgy and archaeology in a new perspective and the result is this book. Looked at from an East and Southeast Asian perspective, South Asian archaeometallurgy and archaeology present new challenges and possibilities which need to be seriously explored.

I am not claiming here to present any new data of my own which I have not already published, but I have tried to provide some new insights and perspectives and presented the data with a different bias this time.

I am really grateful to INSA for sponsoring the Project, to IRCJS for providing valuable facilities and a very congenial atmosphere. In Japan, I got valuable help from my friends Professors Y. Yasuda and H. Tabata. Dr. A.K. Bag of INSA, Prof. U. Kapadia of L.D. Institute of Indology and Dr. R.S Bisht helped in various ways.

Amongst friends, Heather Miller gave her valuable time and all published and unpublished work for liberal use in this book. In fact, for the Harappan material I have drawn mainly upon her and Mark Kenoyer's work. Vibha Tripathi gave a lot of her valuable publications on Indian Iron Age in which she specialises. Richard Meadow and Heidi Miller both gave their unpublished data, photographs and papers for use in this book. Suzanne Young and Paul Budd were very helpful with their published and unpublished works. Donn Bayard sent me even his unpublished Non Nok Tha report. Joyce White was so kind to give me both her Ban Chiang illustrations

and papers. Vince Pigott sent me his valuable comments. Greg Possehl gave me his complete data files on metal analyses though due to problems of software I could not use them. Besides, he is a walking encyclopedia on Indus civilisation so whenever I got stuck up (in Japan), I took full advantage of his knowledge. Paul Craddock sent me practically the whole set of his reprints. They proved so helpful. Virendra Misra was another source of valuable help. Working in Kyoto, where I had no access to my personal library, help from such friends proved invaluable. Dilip Chakrabarti and Rafique Mughal, my old friends now both in Cambridge, have always been a source of great help and encouragement. Sheela Kusumgar and Ashok Singhvi, my old colleagues, have always been very kind, liberal with their data and multiple help.

Of the younger colleagues, Neha Panchal and Jeewan Kharakwal extended their full help and support. My wife Lata has helped me a lot, as always. Despite her busy consultancy, my daughter Ila always finds time to teach me some new tricks with the PC software.

I greatly appreciate the efficiency, quality consciousness and business ethic of my young publisher, Vikasji.

I am grateful to all these people, and to those I have not been able to mention specifically, for helping me in bringing out this book.

D.P. Agrawal

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ABBREVIATIONS

BP	:	Before Present
Pers. comm.	:	Personal communication
NBPW	:	Northern Black Polished Ware
PGW	:	Painted Grey Ware
B & RW	:	Black-and-Red Ware
HARP	:	Harappa Archaeological Research Project
IAR	:	<i>Indian Archaeology — a Review</i>
c.	:	<i>circa</i>
JBORS	:	<i>Journal of Bengal & Orissa Research Society</i>
JBRs	:	<i>Journal of Bihar Research Society</i>
As	:	<i>Arsemitic</i>
Cu	:	<i>Copper</i>
Pb	:	<i>Lead</i>
Sn	:	<i>Tin</i>
Au	:	<i>Gold</i>
Ag	:	<i>Silver</i>
Ti	:	<i>Titanium</i>

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CHAPTER 1

INTRODUCTION

We begin with Cyril Smith's famous words from his *Metallurgy as a Human Experience* (1977), "Materials are indeed the enablers of everything like the electron itself, but operating at a level that is more complexly structured". Smith was a rare combination of a metallurgist and a philosopher and this statement reflects his unified view of the universe (Smith 1981).

Talking of materials (metals), Smith says, "We now have most of the bricks we need and can start the construction of a master edifice with communicating corridors and with communal work space to replace the individual huts in which we have separately lived in the past" (Smith 1977: 5).

He compares the civilisation processes with the physical phenomena. "There was the stage, invisible except in retrospect wherein fluctuations from the status quo involving only small localised distortion began to interact and consolidate into a new structure. This nucleus then grew in a more or less constant environment at an increasing rate because of the interfacial opportunity, until finally its growth was slowed and stopped either by depletion of material necessary for growth or by the growing counter pressure of other aspects of the environment. Any change in condition (thermodynamic = social) may provide an opportunity for a new phase. We all know how the superposition of many small sequential S-curves tends to add up to the giant S-curve of that new and large structure which we call civilisations, and we are beginning to wonder what new structure can be nucleated to prevent decay. The termination of one S-curve marks the limit of growth of one idea or structure; the continuation of the envelope marks the growth of a superstructure, incorporating modifying and sometimes eliminating the previous stages within a large organisation. Because at any one time there are many overlapping competing subsystems at different stages of maturity but each continually changing the environment of the others, it is often hard to see what is going on. Moreover, nucleation must in principle be invisible for the germs of the future take their validity only from and in a large system that has yet to exist. They are at first indistinguishable from mere foolish fluctuations destined to be erased. They begin in opposition to their environment but on reaching maturity they form the new environments by the balance of their multiple interactions. This change of scale and interface with time of radical misfit turning into conservative interlock is the essence of the history of anything whatever, material, intellectual or social. Our professional job as engineers is mainly to facilitate the stage of growth where ends and means are both visible if indistinctly" (Smith 1977).

Smith traces "the earliest evidence for the intentional modifications of properties of natural inorganic materials, i.e., the beginning of pyrotechnology, lies in packets of iron oxide that had been heated to give various colours for use as pigments for the decoration of the human body

and other surfaces. Discovery is less likely to occur when people are desperately earnest than when they are in a sensitive somewhat playful, mood" (Smith 1977: 20).

This book deals with metals, which perhaps made civilisation possible, though not all scholars would agree to this premise. We will explain the contents of the different chapters towards the end of this chapter. Before we do that it may be worthwhile exploring the vast potential of studying metal craft to reconstruct the past. We give below some examples of what can be achieved through a proper study of crafts, as also why at all we should study them.

A scintillating example is Vidale's (in press) stimulating book, *The Archaeology of Indus Crafts*, in which he has made profound observations based on various crafts. He says, "Craftspeople of the Indus Tradition were a fundamental component of the process leading to the Indus civilisation and its later evolution. Their products had important roles in the strategies of social comparison, intra-societal communication and legitimisation of the dominating ideology and social orders. Moreover, Indus craftspeople might have been influential well beyond the boundaries of the Indus core area". In a recent paper, J.-F. Jarrige writes as follows, "Beginning with craft activities, we know that India, across the historical periods, enjoyed a great reputation for the making of ornaments, of every kind of bead, of faïences, of enamelled objects, of ornaments in shell and ivory and of luxury textiles.... Sargon of Agade around 2300 BC, considered the goods from "Meluhha", "Magan" and "Dilmun" so precious that the boats shipping them were meant to sail the Euphrates up to Akkad, without being unloaded, like the rest of the boats, in the port of Ur...some communities of craftspeople played an important role in Mesopotamia, being involved not only in trading raw materials and finished objects, but also in the building of temples. These craftspersons-merchants are somehow the forerunners of the groups of Indians who, using their knowledge and techniques, in the course of centuries settled from Southeast Asia to the eastern coast of Africa".

Jarrige thinks that the development of sophisticated techniques in craft production was an early, distinctive cultural trait of the Indus tradition; that the technical innovations taking place between the 5th and the 3rd millennia BC had an important formative role for the whole Indian culture; that Indian craft traditions had a strong propulsive power, deeply affecting in the course of history the aesthetics and the economies of the surrounding countries and peoples; and he seems to imply that such proficiency in craft production - and, one might add, the underlying organisational tradition - was a continuous Indian tradition from prehistory to the last centuries, when the high technical and aesthetic standards of Indian textiles and other kinds of craft products represented the original stimulus for the settlement of Portuguese, French and English trade colonies along the Indian coasts (indeed, an epochal process).

"In the ancient world, craft was always skilled, sophisticated, well adapted to its social *milieu*, almost by definition. The concept of technical virtuosity in the Indus tradition does not imply that Indus craftspeople were more sophisticated or more specialised than, for example, their Predynastic colleagues in Egypt. It stresses the fact that craft technology, in the protohistory of the subcontinent, seems to be affected, since early times, by intensive processes of experimentation and innovation, resulting in the appearance and rejection of techniques and manufacturing sequences involving a high number of inner steps, mainly thanks to the systematic insertion in the sequences of pyrotechnological processes; and that these techniques allowed the production of sets of objects having the same basic shape, and probably symbolic meanings and functions, but varying in size and aesthetic features, and made of materials of different values" (Vidale in press).

Kenoyer and Miller (1995) think that by expanding their inventories of products, Indus metallurgists provided other highly valuable versions of more common ornaments, utensils and tools. The first metal objects to appear are gold and copper beads in the Neolithic; in the Regionalization Era (Chalcolithic period) other categories of ornaments and several types of stone and bone tools had their copper/bronze versions. In the Integration Era or Harappan Phase, almost every object, including household utensils, craft tools, weapons, were replaced by costly copper/bronze items or had copper/bronze versions. Personal ornaments such as beads, bangles, rings were made out of a long series of base materials: stone, shell, ceramics and fired stones, copper, bronze, silver and gold. It is with the production of such personal ornaments that the Indus attitude reaches its peak at transforming the base material and the manufacturing sequence of classes of similar objects.

Vidale points out that in the Harappan Phase, copper/bronze vessels, to a large extent, faithfully reproduce earlier pottery prototypes. The imitation of metal forms by potters is well known in the archaeology of ancient Europe. But Indus metallurgy, as far as I know, offers us a much rarer example of a contrary trend: luxury metal vessels purposefully imitating in detail the products of a cheaper, common object, which normally fulfilled a daily need at the domestic level.* This intentional imitation is well illustrated by the carinated bronze pots common at the most important excavated sites. These pots reproduce in detail a common ceramic type, the globular cooking pots.

Vidale thinks that stylistic behaviour, marking status differentiation, would be much more effective if activated in contexts of maximum social comparability. In contemporary India, as domestic ware has to be kept far from soiling and pollution, it often hangs on shelves and near the roofs, so that it enjoys a high visibility. In the villages, copper and aluminium vessels are displayed with pride by well-to-do families belonging to the higher caste orders. Upon enquiry, in most cases nobody is willing to admit to use any kind of ceramic vessels for cooking and serving food, mainly because there is the common feeling that earthenware vessels, being porous, may be easily contaminated by polluted food and water, and therefore mark lower castes.

He therefore concludes that by making and using precious bronze vessels morphologically identical to traditional pottery forms, Indus *élite* would signal the existence of a deep social gap within an established behavioural code, compatible with the existing social classifications. In this light, such bronze vessels might have been an obvious and important strategic element for signalling status differentiation. In the Harappan Phase, this evidence gives an example of how material culture might have been used to signal and strengthen social boundaries in the urban society.

Vidale however admits the uncertainties involved in such hypotheses. How far and to what extent metals, and particularly copper/bronze, may actually be considered a valuable, *élite*-related base material? He disagrees with Shaffer's idea that metal artefacts were available to a broad segment of a scarcely differentiated society (Shaffer 1982: 47).

Some authors have emphasised the role played by metal tools in the progressive replacement of a great part of the lithic tools used in domestic work as well as in many different crafts. From the Regionalization Era to the Harappan Phase, various types of small cutting and scraping

* Vidale says, "I have personally observed, in showcases of Genova, in north Italy, replicas of simple earthen flowerpots in an expensive Murano glass, which cost about 150 U.S. dollars, against the price of 1 dollar usually paid for the ceramic pots. Nowadays, very faithful plastic versions of earthen flowerpots are also becoming increasingly common in Italy, mainly because of their practical advantages"

tools, including, for example, denticulated or strongly retouched blades, were substituted by copper/bronze tools. But some highly specialised tools continued to be used. For example, the studies by J.M. Kenoyer and Vidale on the techniques of drilling carnelian beads show that copper drills and abrasives probably were not extensively used by the Indus bead makers, who continued to trade, fabricate and use cylindrical constricted drills of *erectite*. Similarly, a wide variety of blades and microblades, including probably sickle blades, chert micro-drills, polishers and scrapers used in various crafts were not substituted by metal versions.

Vidale holds that in the evolutionary trajectory of Indus technology, lithic tools and industries were not simply an inferior technical option to be replaced by metallurgy, but a dynamic option which systematically occupied "technological niches" not filled by metallurgy. From this perspective, the parties of chert knappers working on the mesas of the Rohri Hills, or the Bronze Age bead makers who invented the constricted cylindrical drills in *erectite*, are not different from the hunter-gatherers who lived outside the pale of urban populations in their own traditional prehistoric economies. They all developed extremely specialised lithic industries, strictly adapted to limited, but important economic activities.

Vidale therefore concludes, "Urban populations and farmers on one side, and hunter-gatherers and nomads on the other, throughout the prehistory of the subcontinent lived side by side and had substantial economic and political interaction. Most probably, in both cases, the processes of technical specialisation underlying the evolution of lithic industries were part of the widespread process of social categorisation and organisation affecting on a large scale the protohistoric societies of the subcontinent" (Vidale, in press).

We have quoted Vidale extensively only to show that through a proper study of material remains, a lot can be learnt about the Indus society and the people. Metal artefacts lend themselves to a variety of analyses, which can be meaningfully interpreted to throw light on the life and times of a protohistoric people.

Heather Miller has also provided deep insights into the Indus society through her intensive studies in pyrotechnology. Another good example of interpretative analyses is Mark Kenoyer's *The Indus Valley Civilisation* (1998). No doubt it is partially speculative, though bold, none of the conjectures appear totally unwarranted. Heidi Miller (see chapter 5) has pointed out that dishes are the preponderant type at Chanhudaro. I am sure, this fact is telling us something important. Could it be due to the predominantly lapidary industry of Chanhudaro? The point I am emphasising is that it is the detailed multifaceted study of artefacts that provides the bones for fleshing out the superstructure (for Indus crafts interpretative studies, see Vidale in press, 1989, 1992, 1998; Kenoyer 1989, 1992a, b, 1997a, b, 1998; Kenoyer & Miller 1999; Kenoyer & Vidale 1992; Heather Miller 1985, 1994a, b, 1997a, b, 1998; Heidi Miller 1998).

Another area where metallurgical studies are helping understand socio-economic patterns of an archaeological assemblage is Thailand. Joyce White seems to have provided some rare insights into the ancient Thai societal patterns mainly based on her archaeometallurgical studies. She says, "The Southeast Asian metallurgical province shows among other things that complex social structure involving slave or highly organised coerced labour is not necessary to the systematic exploitation of metals. Nor does the regular exploitation of metals necessarily lead in rapid order to greater social complexity or militarisation. And most likely, Southeast Asia is not the only case where humankind had an impact on the development of metallurgy". (White 1988: 175-81). In a later paper, she made it clear that elite control is not at all necessary in all societies. She said, "Undoubtedly the trajectory to state formation in a region whose pre-state context is

characterised by developed community-based production systems, decentralised distribution and social heterarchy will have characteristics and developments that differ from regions with clear evidence for development of rigid hierarchies and elite controls over economic sectors. Sure enough, the historians tell us of the extraordinary flexibility in leadership generation, the lack of standardisation in such areas as valuation concepts and the core process of localisation repeatedly evident in the incorporation and transformation of ideas, concepts and practices. The prehistoric record is beginning to reveal that roots of these very processes extend back for over 2,000 years prior to the establishment of states" (White & Pigott 1996: 170).

Though not all agree with their new interpretations, Bayard informs, for instance, that "Despite Higham's 1984 statement that metallurgy must somehow stimulate 'concomitant changes in social complexity noted under similar conditions in the Aegean, Near East or Shang China', there is no reason to suppose that at least 1,500 or 2,000 years of village-level bronze-casting should in some way have contributed to increased social complexity. Metallurgy is surely better considered one of the servants of society than one of its masters" (Bayard, in Non Nok Tha report in press).

As I have discussed in chapters 5 and 6 of this book, the Ganeshwar Complex provides another example. Here non-urban societies seem to have supplied copper ingots and artefacts to the Indus civilisation without themselves getting urbanised.

Coming to more down-to-earth archaeological applications of archaeometallurgy, one could give the example of Chernykh's vast studies in Russia and Europe. Chernykh discusses the correlation between the said Indo-European waves and the three metallurgical provinces of the period - the Balkan-Carpathian Copper Age province, the Circumpontic province of the Early and Middle Bronze Age, and the Eurasian metallurgical province of the Late Bronze Age. He emphasises, "The most vivid manifestation of the active spread of the culture of these people supposedly speaking Indo-European languages, seems to be the formation and disintegration of the metallurgical provinces" (Chernykh 1980: 317-36).

One more such example is the work of Budd & Taylor (1995). They make some interesting observations, "A key point in the development of Old World metallurgy is the transition from bronze to iron as the metal of most common use, but at present there is no adequate social reconstruction of how this came about or, put the other way, what its social consequences were. The oft-cited 'democratising argument' - that iron was widely available and independent of established networks of tin distribution - is not strong enough in itself. Terrestrial iron was being made a full thousand years before its widespread adoption in Europe" (Taylor 1989). And there was enough bronze in circulation in scrap and in hoard for it not to have been in limited supply (if, of course, it really was a commercial 'market' product). One of us has proposed a form of social explanation: 'Bronzsmiths probably operated via ties of clientage. Their overlords were the hereditary controllers of the tin supplies. For iron to establish itself, not only did a predominantly alloying and casting technology had to be replaced by a forging one, but society had to undergo a fundamental reorientation [as]...artisans became less tied to particular tribal groups or lineages'. Such 'blacksmiths' may well have been itinerant, safely providing a range of liminal or magical services to sedentary communities who could keep them at arm's length (i.e. avoid ritual contagion), but actually in contrast to 'bronzsmiths' of the preceding period....

"If military and political leaders were actively and intimately involved in competitive ceremonies of bronze making and the various disposal of its results, we can imagine how they might easily have been overtaken by incoming martial elites from the steppe who 'must have

disrupted the vested interests that maintained the tin supply, at the same time as they glamorised the new technology that they used to such effort ; a Cimmerian or Scythian warlord who depended on dissociated service ethnics for re-arming (cf. Genghiz Khan's gypsy blacksmith, who was responsible for the supply and maintenance of his personal weaponry) would be at an obvious advantage over a 'Bronze Age' chief who would personally have to go through the correct ritual channels in order to re-arm; under such conditions, taking up an offer of the new material by devolving all the problems of ritual contagion on to a travelling stranger could have been tempting" (Budd & Taylor 1995).

Perhaps the downgrading of the Kumauni shilpkars (chapter 8) in social status could be explained by this model when they gave up copper-smithy for iron-smithy.

We have tried to situate the South Asia metallurgical – archaeological evidence in a pan-Asian perspective. For the beginnings of metallurgy, West Asia has played a significant role. But the East and Southeast Asian evidence is often ignored. As pointed out in chapters 8 and 9, there emerges a possibility of very early contacts with China and Southeast Asia through the movements of Mon Khmer people. Some scholars have tried to attribute the so-called Daimabad bronzes to the Harappans. But if we contrast the elitist Chinese monumental bronzes – both statuary and ritual vessels - and the functional artefacts of the Harappans, such an attribution looks totally untenable. This aspect is explained in detail in chapters 5 and 10. Metallurgy also reflects a cultural identity, an individuality, which becomes obvious only if we have a continental perspective.

As we know, copper did facilitate the great Indus civilisational process. What were the factors that helped urbanisation of the Indus valley are discussed, along with metallurgy, in chapter 5. The Indus civilisation was rich in silver too. In fact, Kunal, a Harappan site in Haryana, shows a great abundance of silver artefacts. As there is considerable controversy regarding the sources of silver and its trade, we have discussed this in chapter 5.

In this book, I have covered metal artefacts of not only the Harappans but also of other protohistoric cultures of South Asia (Fig. 1.1), but in a pan-Asian perspective infused with an archaeological bias.

Chapter 2 deals with mineral resources and mining and also the complexities of ore-artefact correlation. Chapter 3 discusses the metallurgical techniques employed in extracting metal and fabricating artefacts and chapters 4 and 5 are devoted to Pre-Harappan and Harappan metallurgy, with an archaeological background. Chapter 6 deals with Copper Hoards and chapter 7 with the Chalcolithic culture.

In the context of Gangetic urbanisation we have emphasised the role of abundance of iron (chapter 9). But it is not so simple, as pointed out by Budd *et al.* (1995). As explained by us in chapter 9, the process of Gangetic urbanisation is quite enigmatic. A number of ecological, technological and resource parameters intermingle to make this process more complex. But again, it is the artefactual study, which will help us unravel these complex processes, of course in the backdrop of ecological constraints.

Ancient metallurgy is a vast field and we have not covered all the metals - but the important ones we have. The emphasis is on copper as it was used by most of the protohistoric cultures like the Harappans, the Chalcolithic and the Copper Hoard people. We have also devoted a chapter (11) to iron as the Second Urbanisation of the Ganga valley was based on iron technology. The Ganga valley is a foredeep caused by the Himalayan orogeny and is therefore filled up with alluvial sediments, covering the mineral outcrops. Though iron appears around the beginning of the first

millennium BC, it could generate adequate agricultural surplus only by mid-first millennium BC to usher the Ganga valley into urbanisation. Of course, the Copper Hoard culture belonged to the Ganga valley too and seems to have enough copper. As the Copper Hoards have been generally found in caches, they give an impression of great abundance of copper, though it may be exaggerated by the nature of the finds. Why the Ganga valley could not produce its first towns by the Copper Hoard people will be discussed in chapters 6 and 11.

This book is focused on South Asian metallurgy, though we have discussed metals in the matrix of archaeology. This required a wider perspective and therefore we have briefly discussed the Southeast Asian (chapter 9) and Chinese and Japanese metallurgy (chapter 10) also.

We have indicated the possibility of early agricultural technology coming down from south China and Southeast Asia through the Himalayan corridors to India (chapter 9). The Japanese technological development has its own peculiarities. It seems that both copper and iron technology came from China to Japan after 500 BC (chapter 10). The Chinese metallurgy, on the other hand, shows an individuality quite distinct from the Indus tradition. Monumentality, both in statues and ritual vessels, is writ large on the Chinese metallurgical tradition. It presents a stark contrast with the Harappan metal tradition which was very utilitarian and no copper was wasted on mere ritual or as a symbol of status. If we look at the so-called Daimabad bronzes in a comparative perspective, they appear totally out of place in the Harappan context, as we have explained in chapter 5.

The antiquity of brass is again a controversial matter. Some brass has been reported even in the 3rd millennium BC. But zinc production through distillation processes was invented by the Indian miners of Zawar in Rajasthan. This required a detailed discussion of early zinc metallurgy both in India and China, as well as in West Asia. We discuss the history of zinc and brass in chapter 12.

Copper by itself is not so hard but can be hammered into hardness. But any such 'cold work' makes the metal brittle. It therefore required addition of arsenic and tin to make it harder yet retain its ductility and malleability. Addition of lead improves the fusibility and was used for improving the casting properties of copper. These alloying elements therefore we have discussed in a separate chapter (13). We have however presented the evidence in a wider pan-Asian perspective.

The last chapter (14) summarises the conclusions and points towards the outstanding problems which need to be tackled in future.

The book depends upon a large volume of both published, and sometimes unpublished, data of other scholars. When the extracts became large, sometimes inverted commas were dispensed with, but the source has always been indicated at the end of the passage/s. I have preferred to use the original language of the various authors, to putting my words into their mouths. The references which are parts of quoted texts are generally not included in the bibliography. Some quoted texts were partially repeated as required by the context.

I must perhaps clarify here that after the eighties, I have not done any original lab analyses, though fieldwork in the Central Himalayas was carried out in the nineties. I would therefore not like to claim that I have put much of my recent original data in this book. As I have tried to provide some new insights and perspectives to the archaeometallurgical data presented here, it is not a mere compilation either. The underlying emphasis has always been archaeology and the human perspective, and not mere archaeometallurgical technicalities.

SUMMARY

I admit that trying to cover so many centres of early metallurgy – West Asia, South Asia, Southeast Asia, China and Japan – is not only ambitious, but even audacious. Such a vast scope of the book required an edited volume with contributions from experts of different areas as was done by Wertime & Muhly for *The Coming of the Age of Iron*. But to present the South Asian archaeometallurgy in an eastern and Southeastern perspective required that one person tries to do it, despite human limitations. The effort was therefore worth its while and I hope will lead to inter-regional research. For those looking for more details, an exhaustive bibliography has been given.

CHAPTER 2

MINES, MINERALS AND OLD WORKINGS

CONTENTS

- INTRODUCTION
- SOURCES OF SILVER
- SOURCES OF INDUS TRADITION COPPER
- INDIAN COPPER ORES
- CHALCOLITHIC COPPER SOURCES
- RECOGNITION OF SMELTED COPPER
- ROLES OF ARSENIC, TIN, LEAD, ANTIMONY, AND NICKEL
- COPPER HOARD COPPER SOURCES
- ORE-ARTEFACT CORRELATION

INTRODUCTION

In this chapter we discuss mainly the sources of silver and copper used by the proto-historic cultures of India. We begin with sources of silver and then go on to the sources of copper used by the Indus Tradition, Chalcolithic and Copper Hoards cultures. Towards the end we discuss ore-artefact correlation problems.

SOURCES OF SILVER

Chakrabarti (1990) while emphasizing the significance of Afghanistan as a positive source of Indus copper, lead and silver, says that each of these metals is easily procurable in Baluchistan, Rajasthan and Gujarat. Ratnagar however thinks that there was no indigenous production of silver in India until a fairly late period, and that the Harappan silver came from Mesopotamia. Chakrabarti argues that this statement does not appreciate the extent to which we have argentiferous galena in the lead-zinc deposits of Zawar and Agucha in Rajasthan. Besides, silver objects are found as early as Nal.

Ratnagar, replying to Chakrabarti's criticism about silver, says that this point about the two urbanised termini of the trade comes across vividly when we consider the trade in silver. Little silver has been found in the intermediate areas of southeast Iran, Seistan, or the Gulf except for two silver artefacts at Shahr-i-Sokhta in Seistan and two silver beads in an Oman grave. She had earlier argued (Ratnagar 1981: 144-46) that the Harappans, the only people of protohistoric South Asia to have used silver on a substantial scale, imported this metal, most likely from Mesopotamia. A regular movement of silver from the Assyrian merchant colonies of Cappadocia

to Mesopotamia is well documented for the period between 1920 and 1750 BC and texts from Ur which refer to silver being taken overseas by merchants to buy copper in Dilmun (clearly an entrepot) date to the time of Rimsin of Larsa or 1822 to 1763 BC. It had also been pointed out that silver occurs in the two large Harappan settlements, Mohenjodaro and Harappa, but is almost totally absent at the other sites.

Another argument for Mesopotamia as the source is that, even earlier, around 3500-3000 BC and also later, silver and lead were used on a substantial scale in Mesopotamia and Elam. One example is provided by the Early Dynastic III Royal Cemetery at Ur, with a truly exceptional amount of silver (Moorey 1985: 114 ff, 122 ff). Second, we now have a run of radiocarbon dates from the silver-lead bearing localities of Dariba, Agucha, and Zawar, near Ajmer in Rajasthan, which testify to mining in the later first millennium BC rather than earlier (Craddock *et al.* 1989). The only earlier mining is attested to at Dariba, but these dates are post-Harappan, viz. later second millennium BC.

Finally it needs to be mentioned that Kosambi (1941/1981) noticed, on a rectangular piece of silver from Mohenjodaro, traces of cuneiform writing. He expressed his surprise that neither Marshall nor Mackay had paid attention to it. But as copied by Kosambi, the cuneiform signs are not complete.

The late Shashi Asthana (1993), who did some very important studies on Indus trade, has made some interesting observations about silver in the Harappan context. Asthana thought that silver was apparently quite popular with the Harappans living at Mohenjodaro and Harappa, but those at Lothal and Kalibangan rarely used it. Silver was used for making vases and ornaments, such as bracelets, bangles and beads.

Asthana also holds the view that possibly the most promising source for Mohenjodaro and Harappa, is in Afghanistan and Iran (Marshall 1931: 675-77). Lead mines, which could have been a source for silver as well, are situated in Faranj in the Ghorband valley of Afghanistan and are common in southern Afghanistan, especially at Hazara Jat. Well-known silver mines are also known to have existed near the head of the Panjsher valley in the southeastern Hindu Kush and in the vicinity of Herat. It was rarely used for making utensils and ornaments. Large finds of lead at Harappa (Vats 1940: 58) and Mohenjodaro include only a lead vase and a lead dish (Mackay 1938: 472), a round lead ball with a copper or bronze staple attached to it (Mackay 1938: 476) and a lump which may be the net sinker (Marshall 1931: 30). Balakot had produced a flat, semicircular piece of native lead (Dales 1979). It seems very likely that the Harappans obtained their silver from Afghanistan... Looking at these resource areas in terms of locational proximity to the Harappan culture area, it can be suggested that the Harappans living in Sind were exploiting sources on the southwestern frontiers (Baluchistan and southern Afghanistan). Northern Iran and Soviet Central Asia were then exploited mainly by the Harappans of the Punjab. Those in Gujarat and Saurashtra were apparently getting their raw materials from the more than adequate sources in their own area, as well as from the South, including Mysore. Northern Rajasthan and Haryana must have taken most of their raw materials from central and southern Rajasthan.

The seven Harappan settlements at Shortugai on the confluence of the Oxus and Kokcha in the Hindu Kush area indicate that the Harappans of the northern region established trading posts to monopolize trade in raw materials from north-east Iran and Soviet Central Asia (Asthana 1993: 271-85).

SOURCES OF INDUS TRADITION COPPER

The question of the supply of copper minerals to the Indus civilisation has been quite controversial. A variety of sources have been suggested right from the early thirties. After presenting a brief survey of the earlier workers' views in this regard, we will try to give a comprehensive survey of the copper mines in India and Pakistan.

Chakrabarti & Lahiri (1996) have recently provided a comprehensive survey of the copper mines and mining areas in the subcontinent. The following account is based mainly on their work, my book and papers (Agrawal 1971, 1982b) and the more recent work of Kenoyer & Miller. Kenoyer and Miller (in Pigott 1999) in a recent review indicate three possible sources for the Indus copper. The first is the combined area of Baluchistan and Afghanistan, to the west of the Indus valley, which extends from highland Badakhshan to coastal Makran. This extensive region contains numerous copper deposits and appears to have the earliest evidence for copper processing. A second potential source of copper is the inland mountain range of modern Oman on the other side of the Arabian Sea, though as we have seen above Chakrabarti does not seem to agree with this view. A third region, to the east of the Indus and Ghaggar-Hakra valley, comprises the north-south oriented Aravali mountain range of Rajasthan. Numerous concentrations of copper ores are found in these ranges along with zinc, lead, and silver ores.

Baluchistan-Afghanistan: This area is full of old workings. Herat, Kabul and Loghar provinces have the major deposits but there are smaller occurrences in the areas of Farah, Ghor, Badghin, Fariah, Jozjan, Bamiyan, Uruzghan, Ghazni, Kabul, Kandahar, Parwan, Baghlan, Kapisa and Badakhshan. There are substantial old workings at Simkoh in Herat, Balkhab in Jozjan and Bazaraka in Kapisa. The old workings near Kabul (22 km to the north-east) showed vast quantities of slag and small rectangular (0.9 by 1.2 m) mining entrances to follow the sloping ore vein which was possibly bornite (Reedy 1992: 243 in Chakrabarti & Lahiri 1996).

In the highland plateau west of the Indus valley flood plains, numerous copper working areas have been reported over the years, but the most impressive is the region of southern Afghan Seistan, often referred to as Gardan-i-Reg (Dales and Flam 1969; Fairservis 1952, 1961). Here in the windswept wastes of the Helmand basin there are vast areas of exposed copper slag mixed with pottery and other cultural debris. Dales (1992) mentions that some of this slag was analyzed and contained 14% copper, and that the gold assay was also quite high, but most of the samples have yet to be studied. The copper ores processed at Gardan-i-Reg are assumed to be from nearby deposits, but no detailed report has been published on the mining areas.

The ceramics and other cultural material associated with the copper smelting debris of Gardan-i-Reg correspond to the Helmand tradition (Shaffer 1992) at the sites of Mundigak, Shahr-i Sokhta (Period III) and Tepe Rud-e-Biyaban (Periods II and III). The dating of the ceramics is disputed and while some scholars feel that they fall between approximately 2500-2400 BC (M. Vidale: personal communication), others suggest that they date to the period prior to 2600 BC (J.F. Jarrige: personal communication). The copper smelting activity would be basically contemporaneous with either the late Regionalization Era ("Early Harappan") or the Integration Era, Harappan Phase of the Indus valley tradition (Tables 5.1 and 5.2). The occasional discovery of Indus valley tradition artefacts at sites in Baluchistan and Afghanistan indicates that there was movement of people and goods between this important mineral resource area and the greater Indus region (Kenoyer and Miller 1999).

Copper occurs widely in Baluchistan. In the Quetta district it occurs at Ziarat, in the Kjojak Amran range and in the hills west of Sohrab and Ghiddar, as also between Sohrab and Rodinjo.

Malachite occurs in large quantities in Jhalawan to the south of Kalat. Chalcopyrite and malachite both occur in the Saruna and Khidrani areas of this territory. Copper is apparently plentiful in Las Bela, in the hills between Liari and Bela where, according to an account of 1840, somebody procured half a mound (1 mound=about 40 kg) of excellent refined copper by smelting three mounds of copper ore. The ore was smelted in a mud furnace with wood as fuel. The Chagai region has three areas of occurrence: Ras Koh in Kharan and Lar Koh, both with chrysocolla as the ore-type and the areas of Robat Koh, Malik-i-Siah Koh and Saindak Koh where there is carbonate of copper in some veins. The extensive presence of slag can be inferred from the fact that at Robat a small fort was built with copper slag as the principal building material. According to Buller, pre-industrial copper smelting was practised in Chagai till the last quarter of the 19th century. On the other hand, some slag specimens from the Sandak mines of the area are dated around 3500-3000 BC.

Copper and iron ores that are rich in arsenic are found in limited distributions in Baluchistan (Agrawal 1971; Sana Ullah 1940) and the Iranian plateau, but it is not clear if these ores were being exploited continuously or only at specific chronological periods. For example, Pigott *et al.* note that the arsenic and lead components in copper objects increase in the later periods at Tepe Hissar in Iran (Periods II and III: c. 3600 to 1700 BC; Dyson and Remsen 1989:108-9) and suggest that this increase is due to selection by the metalsmiths (Pigott *et al.* 1982). On the other hand this pattern could be the result of changing access to copper ores due to political or trade alliances, and not an intentional act on the part of metalsmiths.

In the Northwest Frontier, chalcopyrite and malachite occur in small pockets in Gilgit, Dainyor Nala, Dikut and Pasu, while chalcopyrite, bornite and malachite are present in Dir. From the Potwar plateau small nodules of copper sulphate were reported by Valentine Ball (1881: 226) in the local shale beds. Chalcopyrite and pyrite pockets have been noted in Swat. Coggin Brown and Dey (1955: 153) also reported some copper ore in Chitral and Waziristan.

Oman: Major connections between Oman and the greater Indus region may be inferred from the presence of Harappan Phase artefacts and possible short term Harappan Phase settlements in Oman (Cleuziou 1989, 1992; Cleuziou and Tosi 1989; Tosi 1982; Potts 1990), combined with the presence of shells from Oman at Indus valley tradition sites (Kenoyer 1983). By taking advantage of the monsoon winds, Indus or other maritime traders may have been marketing Arabian copper in the Indus valley, Baluchistan, and Gujarat.

Omani copper ores are similar to those of the Aravalli region of Rajasthan (below) in that they have little or no arsenic and have relatively high quantities of nickel, cobalt, and vanadium (Agrawal 1971: 152, Table 20). They are different from Iranian ores in that they have higher quantities of nickel, cobalt, vanadium, and chromium (Berthoud and Cleuziou 1983). However, in light of the use of arsenic impurities as a sourcing marker by Indus researchers (see below), it is important to note that copper slags and objects containing arsenic have been reported from copper processing sites in Oman (Hauptmann and Weisgerber 1980b:135,137). The sites in the Indus valley flood plains may have imported Omani copper, but probably drew on at least one other source as well.

Mainly because of the cultural contacts between the Indus and Oman, it has been surmised that Oman was a major source of copper for the Harappa culture. But in my opinion the circumstantial evidence goes against this assumption. Heather Miller has pointed out that several copper prills were found to have been discarded without retrieving copper from them. This shows that there was abundance of copper and it was not treated as a precious imported commodity.

On the other hand Ganeshwar complex sites have yielded more than 5,000 copper objects with a number of Harappan types like thin blades, arrow-heads etc. Rakhigarhi was a major Harappan city with the rich copper resources of Rajasthan in its hinterland. Besides, the Mesopotamians imported copper from Meluhha which has been traditionally identified with the Indus region (see chapter 5). In view of this evidence, it does not make much sense to import copper from Oman on any major scale.

West Asian Sources: Wertime (Wertime 1964) says that Ergani Maaden in Central Anatolia and Anarak-Nachlak, about 120 km from Sialk, are the two ancient copper mining centres that stand in reasonable propinquity to the copper yielding old sites of this region (Agrawal 1971: 144-50).

Kenoyer & Miller (in Pigott 1999) state that in the early third millennium BC, there was brisk trade between Dilmun (island on Persian Gulf) and Ur, a port of Sumer. "Copper was supplied in ingots and in the form of manufactured goods too. A lexical list notes three types of copper: 'Copper from Dilmun', 'Copper from Magan' and 'Copper from Meluhha'. The primary purpose in noting the point of origin of the copper probably was an indication of its purity and quality. It is also possible that Mesopotamia imported copper from Anatolia. Probably it was shipped to Tishmurna and Durhumit as 'Black copper' for final refining. Assyrian traders who had their agencies in Asia Minor in early second millennium BC bought 'bad' (black) and 'good' (refined) copper. The ingots were in the shape of ox-hides. The peaks of production are confined to the periods between c.2400-2000 BC and c.1500-1200 BC. The Assyrians also got copper from Urartu (Ararat). Sargon II lists 126 tons of crude copper and hundred of daggers, lance heads and vessels amongst the spoils of wars. Edon near Khirbet-en-Nehas and Umm el' Amad as copper mining area for Palestine and Syria dated back to c.1800 BC. It is estimated that about 1,000 tons of copper were produced in about 1,500 years in ancient Egypt. The main source of Egyptian supply was Sinai, though a few eastern desert mines are also known. The presence of crucibles, slags and copper objects prove that the smelting of ore was already practised in Pre-Dynastic times. Production of the oldest mines in the Wadi Magarah continued (with a break between Dynasties V & XI) to ca. 1750 BC. From 1600 BC onwards mining was concentrated in the region of Sarabit el-Khadim, until it ceased about 1200 BC by which time Egypt had come to depend upon imports from Cyprus and Armenia. Remains of miners, habitations and copper working mark these early mining sites. Smelting was carried out at the spot but refining took place in Egypt. Sinai mines were most important sources till XXI Dynasty. The Kubban mines may have been used from XII Dynasty and Abu Seyal not before XIX Dynasty. Arabah, between Gulf of Aquaba and Dead Sea, too was an early copper mining centre. This was in use from Early Bronze age to the period of Edomites (c. 1100 BC). Cyprus was another important centre. Egypt received supplies from there during Dynasty XIII (c. 1580-1350 BC). These mines also supplied Troy, Crete and Greece and were famous in Homeric times" (Kenoyer and Miller in Pigott 1999).

Moorey (1994) reports that a group of five circular bun-shaped ingots of copper were included in the mid-third-millennium BC 'Vase a La Cachette' excavated at Susa. They have been associated with ingots of this shape found in the Gulf and in Indus valley settlements. Two bun-shaped ingots were found in a contemporary context at Tell Chuera in Syria (Moorey 1994).

INDIAN COPPER ORES

About the Harappan sites, Kenoyer & Miller (in Pigott 1999) say that actual copper minerals

(e.g. chrysocolla, chalcopyrite, malachite, etc.) are rare at Harappan Phase sites in the core areas of the greater Indus valley as are other metal minerals such as haematite, lollingite (iron and arsenic), antimony, cinnabar (sulphide of mercury), cerussite (carbonate of lead), galena, and an unidentified type of lead ore recently recovered from excavations at Harappa. Although some of these metallic ores may have been used in copper melting and alloying processes, such as for colorants, cosmetics, medicines or even poisons. Given the low occurrence of raw materials, it is assumed that most of the initial stages of smelting and preparing ingots were undertaken in remote resource areas near the metal ore and forests that would have been necessary for the preparation of charcoal. Major regions for copper ores are northern and southern Baluchistan, the northern Aravalli range and more distant Oman. It is not unlikely that all of these sources were exploited by the Harappans, stimulating an important market dynamic because of the different types of metals available from each region and the different distances involved.

Copper is widely distributed in nature. Native copper is found on the surface of copper and iron ore bodies.

The main Indian copper minerals are:

1. Chalcopyrite	$\text{Cu}_2\text{SFe}_2\text{S}_3$	34.6% copper
2. Chalcocite	Cu_2S	79.8% copper
3. Bornite	Cu_2FeS_4	55.5% copper
4. Tetrahedrite	$4\text{Cu}_2\text{S} \cdot \text{Sb}_2\text{S}_3$	52.1% copper
5. Covellite	CuS	66.5% copper
6. Malachite	$\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$	57.3% copper
7. Azurite	$2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$	55.1% copper

Present mining areas in India for copper are mainly located in Rajasthan, Bihar, Andhra and Kumaun, though there are several other minor deposits reported from Kashmir, Tibet, Jammu etc.

Bihar: The Singbhum belt extends over a region 130 km long and up to 8 km wide. In 1959 the reserves of copper ore were estimated to be 3.8 million tonnes with an average 2.47% copper content. New explorations have brought to light copper ore resources of Patharghora, Surdha, Kendadih, Roam-Sidheshar area.

Andhra Pradesh (AP): Chakrabarti & Lahiri (1996) have noted the following main copper bearing sites in AP.

The major copper bearing districts of Andhra Pradesh are Cuddapah, Guntur, Khammam, Kurnool, Nellore, Prakasam, Mahbubnagar and Nalgonda, with Guntur and Khammam being the most important. The Guntur belt is 4.8 km long. The district-wise distribution of the localities is the following:

Cuddapah: Velidendla, Chinnakudala, Bestavaripalle, Brahmanapalle, Venkatapuram, Vemula and Midipenta. Native copper is found in the lead mines of Jungamrazpilly (Ball 1881:240).

Guntur: The Agnigundala belt (Karunakaran 1975:22), the most significant copper-bearing area of Guntur contains the localities of Bandalamottu and Peddagavalakonda hills (chiefly chalcopyrite), Nalakonda (bornite and chalcopyrite) and Dhukonda (chalcopyrite and some bornite, of Sivasdas *et al.* 1985:6). Pyrite and stray specks of native copper are found in all these areas.

Khammam: (Chalcopyrite with some pyrite and pyrrhotite) Mailaram, Venkatapuram, Banjar,

Mainkawaram, Rabingudem, Sarkal and Yellambailu.

Kurnool: (chalcopyrite) Gani-Pallava (for the old workings, Satyanarayana Rao 1972:26-27), Kommamarri, Somyazullapalle and Jonnagiri; Nellor (malachite, pyrite and chalcopyrite) Chandraredipalem, Gotigundla, Garimanipenta, Gogupalle, Kottapetta, Rajupalem, Somalregada, Tirumalapuram and Vinjamoor (Karunakaran 1975:23). Prakasam : Gajjalakonda (Karunakaran 1975:23).

Mahbubnagar: Kanrikalwal (Rajagopal 1976:9). Nalgonda: Chintriyal (Rajagopal 1978:13). Satyanarayana Rao (1972:26 ff) describes in some detail the old workings in the Kurnool district. Old workings here are easily identifiable from the dumps of fragments of shale, trap and vein quartz surrounding them and found distributed in the Tadpatri shales formation, the longest stretch being 2.8 km. The size of the workings varies from being mere trial pits to about 200 m long and 16 m wide (Satyanarayana Rao 1972:29).

Rajasthan: In Rajasthan, copper ore mines are located in practically all the divisions. The most important of them are at Khetri-Singhana in Jhunjhuna district. This belt continues from Singhana to Raghunathpura, about 80 km. In this belt, in the Mardan-Kudan section there is a reserve of 28 million tonnes of ore with 0.8% copper and in the Dariba area 0.5 million tonnes ore deposit of 2.5% copper. The mineral found in these places is chalcopyrite (CuSFe_2S_3) which is usually disseminated in schists and phyllites. Below we will note some of the main occurrences and details of copper ores in Rajasthan, as this area has a greater importance for the protohistoric sources. The description is based on Sethi (1956), Dunn (1965), Mujumdar and Rajguru (1962-63), and Srinivasan (pers. comm.), Kenoyer & Miller (in Pigott 1999), Chakrabarti & Lahiri (1996) and (Agrawal 1971). For details of references to mining areas, the last two references may be consulted.

- (i) *Khetri Singhana* (Jaipur dist.)
Outside Singhana several million tonnes of slag heaps are lying. The ore used was chalcopyrite (old name, 'dha'), which occurs with pyrrhotite disseminated in shales, phyllites, schists and quartzites. At places copper content of ore is 0.75 to 4%.
- (ii) *Kho-Dariba* (Alwar dist.)
Ore occurs as veins and lodes in most phyllites along the contact plane separating them from quartzites. The mineralisations of chalcopyrites and chalcocites occur here under gossan area. Incrustations of chalcantite were also seen. Old slag heaps are reported.
- (iii) *Delwara Kirovli* (Udaipur dist.)
Old workings are reported from Delwara, Kotri, Vilota, and Kirovli. Extensive slag heaps were found at Delwara and Kirovli (IAR 61-62). Chalcopyrite and malachite are associated with quartzites and biotite-actinolite schists. Malachite has 6.8% copper.
- (iv) *Debari* (Udaipur dist.)
Ores are malachite, chalcopyrite, cuprite, azurite and bornite. Rajguru and Mujumdar (IAR 61-62) reported many such sites from this area. Some of the openings, e.g. Kotri and Delwara, appear to be very crude and small in dimensions, the deepest amongst these being 36.5 m. There are no ^{14}C dates for these workings.

The slag pieces showed great variation in size, shape, composition, density etc. From froth-like glassy to heavy iron-rich varieties were reported. Portions of clay retorts, crucibles and other pots, as also malachite stained quartz pieces were collected from these heaps. They grouped the slag pieces in the following way:

- (i) Heavy and massive type containing more iron and possibly copper and other silicates.
- (ii) Lighter types with lesser iron and more of silica and other silicates.
- (iii) Glassy froth.
- (iv) Slag pieces fused with clay and fine sand.

Glassy froth found at Ahar from purely Chalcolithic horizons was analysed by Hegde (unpublished thesis). Srinivasan (pers. comm.) has traced the history of Khetri belt workings up to Mauryan times. Abul Fazl (AD 1590) mentions these mines and in recent times Captain Baileau (AD 1830) reported it first. Hegde & Ericson (1985) have done some interesting work on the Aravalli mines.

Kenoyer & Miller (in Pigott 1999) also refer to the previous reports on Rajasthan. The copper deposits in Rajasthan and the Aravalli mountain ranges have been discussed by Sana Ullah (1940), Hegde (1965, 1969), Agrawal (1971, 1984), Asthana (1982), Agrawala (1984a), Hegde and Ericson (1985), Rao (1985), and Hooja (1988: 38), but only a few analyses of ore samples have actually been published. Hegde and Ericson also present results from lead isotope analyses of copper ores from eight sites in the Aravallis (1985:61).

Kenoyer & Miller (in Pigott 1999) further discuss the evidence of the composition of ores. They say, "From mines in Rajasthan (Khetri and Alwar), Bihar (Singhbhum), and Afghanistan they were examined by Sana Ullah, and all contained both nickel and arsenic. Sana Ullah proposed that the Rajasthan (Aravalli) mines were the source for most of the metal used in the greater Indus region, because of their relative proximity to Mohenjodaro and Harappa".

Kenoyer & Miller (in Pigott 1999) also discuss the problem of arsenic in Rajasthan ores. Sana Ullah (1940: 379) did not publish his analyses of Aravalli ores, but Hegde (1969: 227) mentions that his "sample of Chalcopyrite obtained from Khetri showed 4.28% of arsenic". It is interesting to note that Kenoyer & Miller (in Pigott 1999) find that in contrast, copper ore impurities from the region of Khetri reported by the Director, Indian Bureau of Mines (Rao 1985) are:

Lead	: Generally occurs as traces, highest percentage noted is 0.18%
Zinc	: Generally occurs in the second decimal, highest percentage noted is 0.18%
Arsenic	: Generally occurs in the fourth decimal, highest percentage noted is 0.06%
Cobalt	: Around 0.01%
Nickel	: Around 0.05%
Iron	: 15 to 20%

My own analyses of chalcopyrite ores from Khetri (Rajasthan) and Singhbhum (Bihar) yielded less than 0.5% arsenic (1971: Table 20, facing p. 152). My studies (Agrawal 1971) based on trace impurity analyses, though the data were limited, showed the possibility of the Khetri ores being used by both the Harappans and the Chalcolithic people.

Of course, Kenoyer & Miller (in Pigott 1999) are right when they say, "At this point there is no direct evidence for Harappan Phase mines or smelting sites in the Aravalli copper resource areas, even though these areas have been explored by numerous scholars". They further report that the earliest well-dated copper smelting slags are from levels of Ahar dated to the early second millennium BC (Sankalia *et al.* 1969:10; Allchin and Allchin 1982:262; Hegde and Ericson 1985:60). Although Hegde and Ericson (1985) assumed that the smelting furnaces they found in surface surveys in the Aravallis are from the third millennium BC, these furnaces have not

been dated, either by radiocarbon or by associated artefacts. If these sources were actually being exploited as early as the third millennium BC, it is possible that the Indus peoples themselves were not involved in the mining and smelting. These activities may have been undertaken by local communities of the Aravalli region. The Ganeshwar-Jodhpura Culture in northern Rajasthan or the Ahar Culture in southeastern Rajasthan may in fact be some of these groups (Agrawala 1984b; Hooja and Kumar 1995).

Kenoyer & Miller (in Pigott 1999) further note that "Many Harappan Phase sites have been reported in the nearby desert region of modern Cholistan, Pakistan, along the now dry bed of the Ghaggar-Hakra River" (Mughal 1980). This region is close to the copper sources of Rajasthan, and Sir Aurel Stein recovered a copper ingot from Siddhuwala Ther, near Derawar. Many of the sites discovered by Mughal have kilns that were apparently used for "firing pottery, clay objects, bricks and perhaps smelting of copper" (Mughal 1980:96). However, there is no report of ores, slag heaps, or smelting furnaces, which would be required before classifying any of these as copper smelting sites. With the availability of at least three different major source areas in easy reach, it is not unlikely that the larger urban centres used copper from more than one source over the 700 years of the Harappan Phase. Only future systematic studies will provide the necessary data to elucidate these sources, and the analyses of copper ores, ingots, slags, and metal prills on crucibles are particularly needed. However, the regional patterns of arsenic presence/absence already provide some evidence for the exploitation of more than one source of copper metal".

It is not only in the Cholistan region that we have Harappan sites. Rajasthan is full of Harappan sites – big and small. Kalibangan is a major site, so is Rakhigarhi. I think the justification of Rakhigarhi could only be the control of mineral rich hinterlands. I have mentioned elsewhere that the Harappan planning of their towns had some economic basis. Harappa itself commanded the western passes and also the supplies of timber etc. from the hilly region behind. One has also to consider the fact that Neolithic Burzahom in Kashmir has Harappan pottery and beads from Neolithic levels. In return, the Neolithic people must be bartering some commodities. Himalayan foothills have orpiment brought by the glaciers. Could it be that arsenic (orpiment) and copper was being supplied by the Neolithic people of Kashmir (see below)?

Uttar Pradesh (UP): The Ganga valley covers most of UP. As it is an alluvial fill of the foredeep caused by the Miocene Himalayan orogeny, it has no exposed mineral outcrops. Central Himalayas seem to be the only source in the vicinity both for copper and iron.

Kumaun-Garhwal: North of Pithoragarh (Fig. 2.1) near Chandak and east of Kanalicchhina minor veins of pyrite-chalcopryrite are seen within the Gangolihat dolomite. In the Dewalthal area near Almora, the magnesite and dolomite show disseminations of chalcopryrite. All the places having suffix 'Agar' were ancient mining/metallurgical centres. At Rai Agar a 18 m long and 0.5 m wide lode of chalcopryrite and pyrite, with an average copper content of 0.04 to 1.5% has been located. The Bora Agar mineralised zone is about 1.5 km long extending between Tusrani and Dol, and 5.30 m in width with an average copper content of 1.29% (Krishnamurthy and Krishnaswamy, 1986; Pant, 1988).

Raghunandan *et al.* (1981:195 ff.) refer to some more copper workings in the area: the Khanayun-Galpakot-Kimkhet areas in the Naini Tal and Pithoragarh districts over an area of 20 sq. km, the Kanalicchhina, Charandeo, Dungri and Tamakhani mines in Pithoragarh and old adits in the Bageshwar area of Almora. A polymetallic copper deposit has been located near Askot. This is the only occurrence of significance. The mineralisation is mainly represented by sphalerite, galena, chalcopryrite and arsenopryrite, with minor amounts of marcasite, bornite, chalcocite, pyrite,

pyrrhotite, cubanite and stinnite (the occurrence of arsenopyrite is to be noted). The thickness of the ore zone is variable, the average being 4.47 m. The weighted average composition is copper 2.32%, lead 2.64% and zinc 3.95% (Krishnamurthy and Krishnaswamy, 1986). A total reserve of 0.77 million tonnes of copper-lead-zinc ore, with an average grade of 9% metal, has been estimated for this polymetallic deposit by the Geological Survey of India.

Kharahi *patti* is located close to the north of Almora town and extends between Binsar and Bageshwar. The area is known as a traditional centre of metallurgy from times immemorial. Atkinson (1980-81:282) writes that the Gaul mine of Kharahi patti and Sor Gurang mines produced grey copper in small quantity. Tamtyura, Danochhina, Chaugochhina, Kharak-Tamta, Ghingarkhola, Binsar, Bhatkhola, Simsyari, Bihargaon, Uderkhani, Biloni, Agar, Gair-Sikera, Lob and Borgaon (all in the districts of Almora and Pithoragarh) were some of the places where metallurgy was practised in ancient times, according to the villagers, who now inhabit these places. The copper-smiths are known as Tamtas, who are thought to be responsible for introducing copper-smithy in Kumaun (for details of the old metal sites, see Agrawal & Kharakwal 1998, chapter 4).

The Agri people, who are considered expert miners, have been living in Kharahi patti. It is told that Chanauli, Joshi Palari, Uderkhani, Chaugaonchhina, Bihar-gaon, Naial and Kharak-Tamta (dist. Almora, Fig. 2.1) are the locations of first settlement of the Tamta people in Kharahi. The following places are believed to be ancient mining sites, where still traditional metallurgy is occasionally practised:

Khan-garh (Khano-ki-garh)	Copper
Agar	Copper
Chaugaonchhina	Copper
Dewaldhar	Copper

Stephens has given a detailed description of the old workings and the cruel and inhuman pre-industrial mining methods of copper extraction and ore processing in different parts of Kumaun. He reports two types of ore in the region: irregular deposits worked extensively at Dhanpur, Dobri and Al-Agur, and regular nodes distributed from near Pithoragarh to the area south of Badrinath and beyond Pokri. He reports: "This 50 mile long band is the major copper bearing zone of the region, with localities like Rai, Bellar and Barabesi in Kumaun and Gwaldum and Pokri in Garhwal being located here". At Dhobri, Stephens noticed many old workings, which ramified to an extraordinary extent. "The Dhanpur hillside where the formations dipped with the slope of the hill and thus provided easier facilities for mining was burrowed with holes. Situated on the western bank of the Ramganga, the Al-Agur deposit where some old workings went down to great depths contained carbonate of copper and grey copper ore with a little pyrite. The other deposits included Tarag-ke-tal (10 miles north of Dwarahat) and Goron (3 miles west of Pithagora) where the lodes were not rich but the old miners honeycombed them with holes like a rabbit warren, and taking out every particle of copper" (Stephens 1901-02:405). At Rai, Stephens noticed that the ancient miners must have gone down to a considerable depth, as every drive has more or less encountered unsuspected and masked old workings. The whole surface at Rai is honeycombed with irregular burrows of every description. In one of these, the remains of a skeleton partly impregnated with copper carbonate were discovered. Stephens fully described the techniques of pre-industrial miners in the region. The ancient underground works are of the rudest description. A gallery was cut rarely over 4 ft. high, and almost always inclining inwards,

drainage of the mine being ignored. Every little bunch was followed up and fossicked out, with no regard to safety or to regularity. The workmen did not understand attacking a deposit by shafts or levels, and their natural desire was to burrow. To this day it is necessary to carefully watch their descendants, as the native's instinct is to go after each little string or bunch he meets with, and levels or shafts soon get out of line. On one occasion the writer was absent for a month, and on his return he found it necessary to fill in the floor, and reopen a level, which his Paharris had turned into an incline during his absence.

"Timbering is of the weakest description—a forked stick and a cross-piece resting in the fork, or at most two forked sticks, one on each side of the working, with a cap placed in two forks. If a run takes place, and the native escapes, he begins in another place; if he is buried, the mine is abandoned.

"In places where the European would blast, the Indian reduces his gallery to the smallest possible dimensions, or seeks a way round. Sometimes, but rarely, he will soften the face of the gallery by lighting fires or brushwood....If water is met with, the miners either form a line and dip it out, passing the deckshie or earthenware pot from hand to hand, or they incline a number of bamboo troughs in a step-like series, with a receptacle at the end of each. A native stationed here lifts this and empties it into the bamboo above. The water flows along this to the next receptacle, and the operation is repeated....The native tools are imperfect in the extreme—a soft iron pick, with no pole, about 11¼ lb. in weight, a small hammer, and a few wedges. No shovel is used, but a sort of hoe is employed to scrape back the broken ground from the face. Wheelbarrows are unknown; either the broken ore is dragged out on a flat hide, the four corners of which are attached by grass ropes to the waist of the human beast of burden (often a woman); or baskets were loaded and carried on the head or shoulder. There are no lamps, occasionally splinters of resinous pinewood, which give a bright but very smoky flame, are employed. A few minutes of this sort of illumination is enough for the European, but the natives often prefer to work in the dark, especially when their burrows are hot and close.

"Such operations cannot be called mining. Probably these Paharis are about the most primitive of all underground workers. Content to live on 2 or even 1½ annas a day, in a country yielding two crops a year on the merest scratching of the soil, necessity has never sharpened their inventive faculties" (Stephens 1901-02:393-414).

Jammu, Kashmir and Tibet: Chakrabarti and Lahiri (1996) summarise the evidence. A number of sites have been reported from this region (Vardan 1976a: 44-46; Raghunandan *et al.* 1981:186-87): malachite stains on the slopes of the Mammal and Dunpathri and sporadic mineralisation in the Shumahal area, all in Anantnag; pyrite and arsenopyrite on the Lashtal hill spur in Baramulla; the report of copper near Purnihal Pathri and in Bazan Nar area of Ganderbal tehsil in Srinagar; the occurrences at Rollu, Duligam and Dedni in the Doda district of Banihal; copper mineralisation in several localities of the Doda district of Banihal; copper mineralisation in several localities of the Doda and Luneak valleys of the Zaskar range in Ladakh; chalcopyrite with malachite and azurite in the Kunzmala formation and malachite at Akche in the same region. Perhaps more importantly, native copper is found disseminated in the geological formation of 'The Volcanics' at Tamze, Kamal Tokpo, Tungri, and Sirtung Nala. Large irregular masses of native copper were found in the Zaskar river as early as 1878 (Ball 1881:267). It is not without reason that in the Ladakhi language 'Zaskar' means 'copper fort' (Raghunandan *et al.* 1981:186). Dudura near Katra in Udhampur district in Jammu has shown stains of malachite.

The areas, which have major clusters, of old workings are in the Banihal, Anantnag and

Baramulla districts. In the Shomal area of Anantnag, the shafts are about 2 m wide and 10 m deep while at Mamal, also in Anantnag, the hillside showed pits, generally 10 m deep and 5 m across. The old workings at Lashtear in Baramulla showed more complexity: the main shaft (1 m wide) goes down for 3 m, levelling off for about 5 m to terminate in a room of about 10 cubic m. The shaft leading to it is about 2 m high. From the room like space itself, a shaft (1 m high) goes down steeply to come out of the side of the hill where the terrain is flatter and more accessible.

Himachal Pradesh: Chalcopyrite and pyrite with some secondary chalcocite, malachite and azurite are spread along 13 km in the Shallu valley from Atoll to Batera in the Simla district. The Chisani, Maol, Malanna, Kot Kandi, Chitrani, Shatgurh near Jerri and Kanor khad localities in Kullu showed copper, in addition to Narnaul and Danala where the mineralised zone extends for about 10 km in the Garsah valley, Uchich in the Parvati valley where pyrite and arsenopyrite occur at the silver workings and the Kullu Bijnar area where there are about 20 occurrences. In Sirmur, malachite stains were noted at Banal. Old workings with slag heaps have been noted in the Garsah valley, near Chisnai and in Sirmur (for details, Raghunandan *et al.* 1981; Ball 1881).

Haryana: In Haryana there are several areas of copper occurrence: the region between Khetri and Khodana in Narnaul; the Golwa-Gangutanna area of Mahendragarh where the 4-40 m wide mineralisation zone extends for over 4.5 km; and the locality of Tosham. Old workings occur at Khodana but more extensively in the Narnaul area, between Dhani-Umrabad and Khalra hills and in Teejanwali and the Luni hills (Raghunandan *et al.* 1981:188).

Gujarat: The following areas are noteworthy (Raghunandan *et al.* 1981:58): Deri-Ambamata, extending for 8-10 km from Sirohi to Banaskantha; Kui-Chitrasani, extending over 45 km in the same Sirohi-Banaskantha stretch; and Champaner where mineralisation occurs in the Panchmahals and the Baroda districts. Native copper occurs in vesicular basalts of the Deccan trap in a number of localities: Beh, Sherdi, Buri and Athmanabara in Jamnagar, and Moj Dam, Jetpur, Virpur and Bhayvadar in Rajkot. The extent of pre-industrial workings in the region can be gauged from the fact that in an area of less than one-fourth of a km between Ambamata and Kumbaria, slag heaps weighing as much as 0.6 million tons and containing an average metal content of 6.2% have been found. An old copper working has also been noted at Jhari in the Panchmahals (Chakrabarti & Lahiri 1996).

Maharashtra: Copper ores are disseminated in the Nagpur, Chandrapur, Bandara and Ratnagiri districts (Raghunandan *et al.* 1981: 49-56). At Pular-Parsori in Nagpur the mineralised zone is about 3 km long. At Dangarmunda in the same district chalcopyrite and malachite encrustations have been noted. At Thanewasna-Chandrapur the strike length comprising chalcopyrite, arsenopyrite and pyrite extends for about 30 km and includes the localities of Bhajgaon, Lalhetri, Dhanur, Dubharpeth, Ghot and Govindpur. Chalcopyrite and pyrite have been noticed at Mendki in Bhandara whereas chalcopyrite associated with a small amount of bornite and pyrite has been found at Kolapur, Jalakwadi, Rasin and Sirsondia. Furthermore, if M.K. Dhavalikar (1975-76:72) is to be believed, native copper occurs at Rashin in Ahmednagar and chalcopyrite around Sirur in the same district (Chakrabarti & Lahiri 1996).

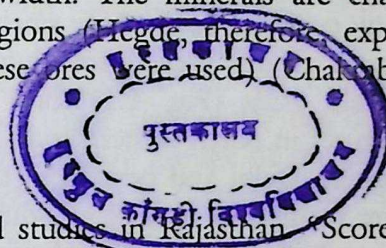
Madhya Pradesh: In several areas (Dinara, Burua Nallah, Narowa, Nadawan and Bijrawan), Shivpuri shows traces of copper mineralisation and the same is true of the areas of Tamakhan, Jinwani, Kothkhera, Kanjikhara and Mirzapur in Dewas (Roy Chowdhury 1955: 32). But the more important copper belt in this region is the Sidhi-Shahdol-Jabalpur belt where there are major occurrences of copper, lead and zinc ores near Sukwari, Bagwari, Byriah, Cherke, Kira,

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Kawakup, Sleemanabad, Imalia, Newalia and Bhulla (Raghunandan *et al.* 1981: 39). In addition to the Malanjikhand deposit where open cast mining is practised by the Hindustan Copper Ltd. and which contains chalcopryite, pyrite and molybdenite (strike length 2.6 km); Balaghat possesses copper-bearing localities at Bhauna-Pahar, Taregaon and Khandapar (Raghunandan *et al.* 1981: 39-42). The copper bearing localities in Bastar are Netanar (malachite, azurite), Mudenar (malachite and chalcopryite), and Mundatikara (chalcopryite, pyrite and bornite). In Chhatarpur, traces of chalcopryite, pyrite and arsenopyrite have been reported in the Salaiya-Jamtoli area. Chalcopryite occurs at Kurnol, Bhagesh, Girjora and Lakhnauti in Gwalior. Cerussite and chalcopryite are noted at Bhelai and Dhorpur for a strike length of 15 km in Surguja. Old workings have been noted all over the region: a number of places in Gwalior, Shivpuri, Bhilsa and Dewas (Roychowdhury 1955:32), Netanar and Mudenar (vertical shafts and galleries) in Bastar and around Bahera-Baheria in Sidhi (Raghunandan *et al.* 1981: 42 ff). Ore deposits of Jabalpur area are very poor. The veins of copper minerals are only 7 to 15 cm in width. The minerals are chalcopryite and tetrahedrite. These ores are in dolomite limestone regions (Hegde, therefore, expected calcium to be present in the Chalcolithic artefacts, in case these ores were used) (Chakrabarti & Lahiri 1996).

CHALCOLITHIC COPPER SOURCES

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Hegde and Ericson (1985: 59-70) have done detailed studies in Rajasthan. Scores of Copper-Bronze Age sites, two of them located within the Aravalli Hill copper ore belt, have been excavated in India. But none of them has revealed stratified evidence of structures that could be identified as copper smelting furnaces. Nevertheless, there is evidence to believe that copper was smelted from the Aravalli Hill copper ore deposits during the Chalcolithic period. For example, one of the Aravalli Hill sites, Ahar, has yielded, together with copper tools, chunks of semi-fused glasslike material which we have identified as copper smelting slag. A trace element impurity pattern comparative study on excavated artefact samples with the Aravalli Hill copper ore deposit samples has also suggested the possibility of linking the artefacts with the Aravalli Hill copper ore deposits. In order to gain a greater degree of certainty for this observation, a lead isotope assay of ore and artefact samples is now in progress. To increase our understanding of ancient Indian copper ore mining and smelting methods, we carried out a survey of six ancient copper ore mining and smelting sites in the Aravalli Hills. In this survey we have found interesting evidence enabling us to reconstruct the early methods of locating copper ore-bearing hills, methods of gouging superficial gossan cap and ore dressing near the mouths of mines. We have also found ore-crushing pits near the foot of ore-bearing ridges where roasted ore was crushed into fine powder; gravity separation devices where powdered ore particles were concentrated, and extensive slag heaps associated with broken pieces of tuyere and the remains of small, crucible-shaped furnaces.

"For example Ahar, one of the early metal using sites located near Udaipur, within the copper ore belt in the Aravalli Hills in Rajasthan (Fig. 1.1), has yielded in levels dated between 1800 and 1600 BC (Sankalia *et al.* 1969) a number of copper axes, chisels, rods and other heavily corroded copper objects of indeterminate use, together with heaps of chunks of semi-fused glasslike material. The excavators of the site had sent us the copper tools and samples of the glasslike material for examination. Analysis of the glasslike material revealed a high percentage of silica, iron oxide and 0.67 to 0.91% of copper oxide (Hegde 1969). We have been able to identify the glasslike material as copper smelting slag. Ahar therefore could be said to be a copper smelting centre of the Chalcolithic period.

"Within the area inhabited by the Chalcolithic communities in northwestern India, extensive copper ore deposits in the form of chalcopyrite, malachite and azurite are found in discontinuous belts in the Aravalli Hills. At a number of places these deposits are marked by shallow gouged pits as well as deeper shafts and extensive slag heaps, representing marks of ancient mining and smelting activity. A spectrometric study of copper ore samples obtained from these ancient mining pits and metal samples cut from representative artefacts selected from widely distributed sites located at Mitathal, Ahar, Somnath, Navdatoli, Jokha and Dhata (Fig. 1.1) showed an agreement of over 92% in impurity patterns and, more important, artefacts did not show any elements that were not present in the ore samples (Hegde 1965).

"The suggestion that the copper ore belts in the Aravalli Hills possibly supplied copper to the Indian Chalcolithic communities settled over an extensive area was encouraging. We considered that an investigation of six selected mining and smelting sites in the Aravalli Hills might reveal details of the ancient mining and smelting techniques. Since none of the excavated sites revealed any evidence of the early smelting furnaces, we thought that we might find evidence of their structures at the ancient smelting sites.

"The Aravalli Hills (Fig. 1.1) form one of the most dominant as well as picturesque geomorphic features in north-western India. They extend over a thousand kilometres from Gujarat in the southwest to Delhi and beyond in the north-east. These hills include steep, discontinuous ridges that were formed by repeated folding and faulting of the Archaen ultrabasic rocks. These deformations resulted from pre-Cambrian plate tectonics of the proto-Indian subcontinent. Geologists have given a detailed account of the mechanism of plate subduction that gave rise to metallogenesis through hydrothermal deposition along the shear zones. They have located seven shear zones in the hills (Sychanthavong and Desai 1977). All the shear zones are rich in base metal ore deposits. The north-eastern zones are rich in copper and contain negligible lead and zinc, which together constitute less than 0.004, while the central and south-western zones are rich in lead and zinc but rather poor in copper, containing only 0.5 to 2.5% of copper. But all the seven shear zones show evidence of their exploitation for extraction of copper in the past.

"Analysis of copper and bronze objects of the Chalcolithic period excavated from sites in north-western India, has shown about one or more than one per cent of lead in their composition (Hegde 1965). Their metal, therefore, was not obtained from the copper ore belt in the north-eastern part of the Aravalli Hills.

"At the central and south-western zones of the copper ore belt in the Aravalli Hills we found much evidence of superficial gouging of the oxide rich gossan cap. A large majority of these pits measure seven to eight metres in diameter and three to four metres in depth. There is evidence of fire-treating of the host rocks on the mine walls to widen the rock joints and thus facilitate extraction of copper ore bearing minerals.

"According to Bateman (1950), the weathered upper part of a metal ore has two characteristic zones. The primary metal sulphide ore veins are converted by the action of oxygen and water into metal oxides, carbonates and sulphate. These are concentrated immediately below the ground-water level and also at the top gossan zone. We therefore wanted to find out if the early miners exploited only the shallow, three-to-four-metre deep, poorly represented gossan cap, or whether they also penetrated deeper to exploit the richer re-deposited minerals and also the primary chalcopyrite lenses below the weathered zones.

"At all the six sites we visited we also noticed mine shafts that were very deep. All these deep mines opened into galleries and narrow tunnels following the natural configurations of ore

veins at different levels. These galleries were provided with ventilation holes at regular intervals.

"We consider the superficial shallow gouging pits as the earliest attempt at mining copper ore in the Aravalli Hills. Deep shafts complete with galleries, stopes, adits and ventilators may perhaps represent later mining activity.

"There is, however, evidence to believe that at least some of the deep mines were worked during the Chalcolithic period. Timber supports recovered from a gallery at a depth of 120 metres at Rajpura-Dariba mines in Udaipur district were dated by radiocarbon to 3120 (160 years before the present). That is the last quarter of the second millennium BC when the Chalcolithic communities were still active in many parts of north-western India.

"We found the evidence for the first step towards ore concentration near the mine mouths. Near all the mine mouths we found large heaps of road metal size waste debris and road metal size chunks of malachite-bearing rocks. These selected ore-bearing rock pieces were roasted, crushed, concentrated and smelted. We have not found any evidence for reconstructing the method of ore roasting. But the small size of furnace that was used for smelting and the high yield of metal that was extracted in it, suggest that the ore was roasted and the smelting technology was efficient. Such an efficiency would not have been possible if the ore was not well roasted to convert all copper minerals in the ore into copper oxide and render the ore pieces porous and fragile and hence easy for crushing. We have found many groups of ore-crushing pits near the foot of the hills. Larger pits among them measure 60 cm in diameter and 70 cm in depth. Smaller ones measure 30 cm in diameter and 40 cm in depth.

"The finely crushed ore was concentrated by gravity separation at the smelting sites which were invariably located near the banks of hill streams. It is a smooth, gently inclined rock surface, nearly marked with rows of round shallow pits, 3 to 4 cm in diameter and 3 to 4 cm in depth. The finely crushed ore was allowed to slowly flow down the inclined plane and thus, by repeating this process, much of the gangue was effectively separated from the ore.

"At the smelting sites were found large slag heaps spread out in terraces, littered with broken remains of furnaces and broken tuyeres. On some of the slag pieces was found the clear cylindrical flow structure, suggesting that the furnace used for smelting the metal had provision for tapping slag. Among the slag pieces we also found large, circular, 18 to 20 cm diameter chunks which the present day local farmers have used for building hedge walls around their fields and homes near the smelting sites.

"Using the evidence of broken parts of furnace, tuyere, tapped and massive chunks of slag, shape, size and weight of the extracted copper ingots recovered at Chalcolithic sites, we have made an attempt to reconstruct the ancient Indian copper smelting furnace and its technology.

"Furnace remains show that they were all broken at the bottom. It appears that there was no provision to tap the extracted molten metal out of the furnace. The ingot was left in the furnace and allowed to cool. Then the bottom part of the furnace was broken to take out the ingot. The furnace therefore was used for a single smelting operation.

"An examination of the unbroken upper part of the furnace shows the following interesting features: the furnaces were all of the same size, small, simple and inexpensive. They were made of coarse, not much elutriated, locally available, stream bank clay. All the broken parts show near uniformity in their curvature and thickness. They show finger impressions on their inner side only, indicating that they were made on moulds by spreading a 2 cm thick layer of clay. These curved pieces also show intact rim portion and lateral edges, thereby further indicating that the ancient furnace was a composite structure, made up of three separate curved parts, each part

representing one third of a conical structure. One of the three segments of the furnace had a tuyere luted to it when it was leather-hard. The angle of luting was approximately 30°. On another segment a hole was made at a height of 5 to 6 cm above the bottom, for tapping slag. Production of furnaces in three separate segments and assembling them together appear to have facilitated their manufacture in large numbers at less expense.

"The interior of the tuyere pipes shows bamboo bark impressions indicating that they were made by rolling a layer of 1 cm thick clay over 15 cm long, 3 cm diameter bamboo pieces. It is not without interest here to note that this was also the method that was used for making tuyeres for iron smelting furnaces until about 50 years ago in our country.

"The furnace was assembled by putting the three curved parts together, one of them containing the luted tuyere, another with the slag tapping hole and a plain third one.

"We did not find the bottom part of the furnace. We have reconstructed it using the size and shape of the copper ingots recovered in the excavations of Chalcolithic sites at Lothal, Harappa and Mohenjodaro. At all these sites the ingots were shaped like a bun. Since the flat portion of the bun is uneven and irregular and the curved portion is regular, we have inferred that the curved portion represents the curved bottom of the smelting furnace.

"No report of metallographic study of these buns has so far been published. We do not know if they are porous, or contain cuprous oxide and slag inclusions. The Lothal bun is 10 cm in diameter, 4 cm in height and weighs 1,438 g (Rao 1973). We have used the curvature of the bun and its diameter to reconstruct the bottom part of the furnace.

"The assembled furnace therefore was small, barely 35 cm in height, 18 cm in diameter at the rim, 14 cm in diameter at a mid-level as the average diameter of the furnace. Its capacity, (Pr^2h) is 5390 cc. This small capacity of the furnace and the relatively high yield of the metal as represented by the weight of the copper ingot buns, enable us to infer that the ancient smelting process was rather efficient. To attain that efficiency, adequate roasting of the ore to convert all copper minerals into copper oxide was necessary. Only copper oxide contains over 80% of copper. It is also the easiest mineral for reduction into metal. It therefore appears that the handpicked, road metal size chunks of copper ore were well roasted to convert all copper minerals into copper oxide. The roasted ore was finely crushed. It was then well concentrated under gravity separation. For preparing the smelting charge it was mixed with crushed quartz, about equal weight of the ore and crushed charcoal, and about twice the weight of the ore. Quartz was used to flux the ore and more important, to sequester it on in the molten slag. Good quality was locally available in abundance. We have noted above that the Aravalli Hills are rich in quartz veins and the hill slopes are littered with chunks of quartz. We have also noted large quantities of these chunks at the smelting sites.

"The evidence of tuyere luted to the furnace wall suggests that the smelting process in the furnace was carried out with the help of the forced draught. But it is not easy to force a draught into a furnace when it is filled with a mixture of finely powdered smelting charge. This prompted us to re-examine the interior of the broken furnace remains more closely to find out if there was any tell-tale evidence to indicate how the furnace was charged. This examination revealed spherical, fist-size lumps sticking on to the interior of the furnace walls. Samples cut from these lumps under the microscope showed vesicular structure, crushed particles of quartz and slag. These lumps therefore appear to be the remains of smelted charge. Their fist-size and small, spherical shape indicate that the crushed ore, flux and fuel mixture was charged into the furnace in the form of small, handmade, fistful of spherical lumps. From the capacity of the furnace, it appears

that about 40 lumps, each weighing about 100 g, could have been charged into it and maintain the domination of reducing atmosphere through an excess production of carbon monoxide over carbon dioxide. As the first charge was smelted, more lumps and fuel were added until an optimum was reached.

"The main component of the slag is fayalite; it melts at 1170°C. The cylindrical flow structure of the tapped slag suggests that the charge was smelted in the furnace at a temperature much above 1170°C. As copper melts at 1083°C, the extracted liquid metal collects at the bottom of the furnace, because of its high specific gravity of 8.89, below the molten slag whose specific gravity is 4. Towards the close of operation slag was tapped by opening a way out for it through the slag tapping hole and the loose earth surrounding the furnace. It appears that the slag tapping segment of the furnace was arranged towards the edge of the terrace so as to let the slag drain out easily. When much of the slag flowed out in this way, the slag in the upper part of the furnace, along with the still burning fuel, piled up over it and collapsed into the furnace forming the massive chunks of slag which the present day local farmers have used to build hedge walls. When the furnace was cooled, the copper ingot was taken out by breaking its bottom.

"From the foregoing discussion it appears that the ancient Indian copper smelting furnace was a small, crucible-shaped, clay-walled, slag-tapping furnace worked on forced draught blown into it from bellows. It was a composite structure made of three moulded segments. Evidence found at the smelting sites shows that it was set up on a brick platform and was surrounded with bricks and earth to keep the three segments of the furnace tightly in position and also to conserve the heat within the furnace. At these sites we have also found terracotta clasps that joined the tuyere and the nozzle of the bellows. This simple furnace appears to have been continuously used in India over the millennia without any innovation" (Hegde & Ericson 1985).

Chalcolithic artefacts

Rapp (in Maddin 1986) has done some valuable work on the chalcolithic artefacts. The following is based on his study.

Rapp says, "The earliest 'alloys' contain appreciable quantities of arsenic and lead, sometimes nickel or antimony, and occasionally silver, bismuth, or tin. A primary question is whether the arsenic, lead, and tin were initially added deliberately or were the result of impure raw materials". If the early arsenical coppers were deliberate, as Charles (1967) and others believe, then what prompted the initial effort(s) in smelting "mixed" ores? Was it random experimentation with metallic-looking stones or the result of perceptive understanding of the smelting products of naturally complex ores?

"Mckerrell and Tylecote (1972) firmly believe that metalsmiths in the Scottish Early Bronze age selected their ores to control the properties of the bronzes. They point to distinctly different compositions for halberd-rivet pairs, the rivets being of a softer alloy. However, it seems just as reasonable that the Scottish metalsmiths were simply perceptive enough to see that sometimes their products were softer and then used those for rivets. The wide range of all components in early alloys does not indicate careful selection of ores and careful control of compositions. Rather, the smiths chose wisely among their metal stocks when making an implement where certain physical properties were needed.

"Throughout much of the eastern Mediterranean and Near East it is difficult to get Chalcolithic and Early Bronze Age copper-based metal artefacts for analysis. Hence the Archaeometry Laboratory has undertaken a study of Chalcolithic material from India. Table 2.1

presents thirteen new analysis from the Chalcolithic of India. As can readily be seen, ten of the samples are unalloyed copper (less than 1% of any alloying element), whereas the remaining three (numbers 1, 6, and 10) are arsenic bronzes with 2.06%, 2.40%, and 4.84% arsenic, respectively.

"In only one specimen (number 5) was tin present in an amount greater than 0.03%, and in this specimen it was less than 0.2%. Zinc is not abundant in these Indian Chalcolithic artefacts. In six of the ten artefacts not considered to be alloyed copper, the proportion of arsenic still ranges from 0.13% to 0.68%. Lead is present in amounts greater than 0.11% in six of the ten specimens. Nickel is present in concentrations above 0.11% in only three of the ten, and antimony is present in only one of the ten. Specimens 1 and 11 contain 2.5% and 2.6% iron, respectively. Specimen 11 showed an iron content of only 0.15% when re-analyzed after the ferromagnetic particles were removed.

"Of the three arsenical coppers one was a weapon and two were ornaments. There is no correspondence between chemistry and function. These specimens are from the excavations of the Department of Archaeology, Deccan College, Pune, India".

Table 2.1 Analyses of Chalcolithic metal artefacts from India (after Rapp 1986)

Lab. No.	Cu %	Sn ppm	Zn ppm	As ppm	Pb ppm	Sb ppm	Ni ppm	Fe ppm	Item	Locality
1	88.65	7.74	296	20,650	5,340	2,460	5,950	25,710	copper axe	Ahar
2	99.91	10.4	<47.9	32	6.7	351	235	<47.6	copper axe	Navadatoli
3	100.9	42.5	<44.5	4,420	689	34.3	40.4	<44.3	copper axe	Chandoli
4	99.11	135	<49.6	6,810	365	42.7	179	402	copper axe	Jorwe
5	96.9	1,985	<50.1	1,300	1,180	44.5	38.8	289	copper bangle	Nevasa
6	95.56	<5.8	<49.8	24,000	1,220	213	1,120	1,360	copper bangle	Kayatha
7	98.23	181	51.4	1,840	6,490	30	591	<80	copper anklet	Inamgaon
8	99.12	119	<49.4	53.3	463	45.7	102	<77.7	copper bangle	Inamgaon
9	98.84	29.4	<52	490	439	45.8	60.8	<81.2	copper anklet	Inamgaon
10	95.45	61.4	<39.4	48,400	707	37.9	3,500	<125	copper bangle	Inamgaon
11	96.2	171	41.4	641	3,680	22.9	90.2	26,100	copper bangle	Inamgaon
12	99.9	244	<34.7	1,390	3,570	39.1	206	<110	copper anklet	Inamgaon
13	99.84	308	<33.1	1,610	676	34.1	124	<105	copper anklet	Inamgaon

RECOGNITION OF SMELTED COPPER

Rapp (1988) gives the following criteria for the recognition of smelted copper. "A number of archaeometallurgists have investigated or commented on the possibility of recognizing unalloyed smelted copper [for example, Coghlan (1962)]. In a recent study Maddin *et al.* (1980) concluded that no adequate criteria exist for distinguishing artefacts of native copper from those of worked and recrystallized smelted copper of high purity. They presented chemical and metallographic data. Adding to my earlier observations (Rapp 1962), I want to suggest that careful investigations of the chemistry of artefacts and related ores frequently can lead to distinguishing smelted copper from native copper".

Table 2.2 summarizes the results of Rapp's Archaeometry laboratory analyses of over 1,000 native copper samples collected from geological deposits throughout the world. The reason that

some elements have lower N's (the number of samples analyzed) is that, from the beginning of the analytical programme nearly two decades ago, they have regularly increased the number of elements sought (Rapp 1988).

Rapp says, "One of the chief values of Table 2.2 is that it presents the maximum concentrations found for the various trace elements of native copper". Thus it serves as a guide to limits of chemical discrimination for native coppers. The maximum value reported in Table 2.2 can be taken as the maximum value likely to be found in artefacts made from native copper that has not been melted or chemically altered.

Table 2.2 Impurity elements in native copper

Element	Mean (ppm)	Maximum (per cent)	N
Ag	238	2.90	1,065
As	976	8.60	851
Au	0.18	0.0014	864
Cd	3.8	0.044	851
Ce	4.8	0.052	864
Co	14	0.38	1,065
Cr	9.4	0.11	1,065
Cs	11	0.091	851
Fe	970	5.00	1,062
Hf	0.96	0.0087	854
Hg	17	0.1200	1,065
In	13	0.12	864
Ir	0.12	0.0012	864
Mo	4.6	0.0075	478
Ni	110	3.20	851
Pt	1.1	0.0097	467
Re	0.13	0.0034	478
Ru	3.4	0.20	851
Sb	4.4	0.089	1,065
Sc	0.43	0.0067	1,065
Se	9.4	0.31	1,065
Ta	0.09	0.0035	851
Te	4.0	0.11	851
Th	0.51	0.004	851
Zn	170	8.20	851
Zr	19	0.12	478

"A special look at arsenic, antimony, cobalt, iron, nickel, silver, and zinc seems warranted. Of the 851 native coppers analyzed for arsenic, 19 contain over 1% arsenic and 44 (5.1%) contain over 0.3% arsenic. The mean arsenic content in native copper is 0.09%. These data may be somewhat skewed because of the large number of Lake Superior region samples in the database. Domeykite and/or algodonite are also found in England, Germany, Iran and elsewhere.

"Antimony, on the other hand, is present only in very low concentrations in native copper. Not one specimen out of the 1,065 analyzed has over 0.01% antimony, and the mean value is only 4 ppm. If copper ores of the tetrahedrite-tennantite (Sb-As) group were smelted, as suggested by McKerrell and Tylecote (1972) and others, the resulting alloy should contain much higher concentrations of antimony than are found in early copper-based metals. Likewise, the concentrations of cobalt in native copper are very low. Only one specimen in the 1,065 analyzed had over 0.01% cobalt.

"Of the 1,062 native copper samples analyzed for iron, 17 (1.6%) had more than 1% iron. The maximum was 9.1% and the mean was 0.09%. It appears that iron is not a good discriminator.

"The data for nickel show that only 16 of the 851 samples analyzed had more than 0.10% nickel. Only one (containing 3.2%) had more than 0.63%, and the mean is only 0.01%. Therefore copper artefacts with more than 0.70% nickel must have been smelted. Some of the Harappan copper has more than 0.70% nickel (Agrawal 1971), as do some early Syrian, Sumerian, and Indian bronzes (Chang and Schwitter 1957).

"Of the 1,065 native coppers, 36 contain more than 0.05% silver and 5 contain more than 1%. Silver is a good discriminator element for distinguishing among native copper deposits, but with its wide range of concentrations it is likely to be less valuable in assigning artefacts to ore type.

"The maximum percentage of zinc in native copper as shown in Table 2.2 is somewhat misleading. Of 851 samples analyzed, 1 showed 8.2% zinc and 1 showed 1.9% zinc. However, these two samples were from the Franklin, New Jersey, zinc mine, and it is likely that the high values are from microscopic zinc minerals admixed in the native copper. For all other native copper localities, only seventeen have over 0.1% zinc, the maximum being 0.58%.

"Two decades ago Friedman *et al.* (1966) presented the results of an important investigation into the minor and trace elements found in copper that could be used to assign the copper to ore type: native copper, oxidized ore, or reduced ore (sulphide). They found that silver, arsenic, bismuth, iron, antimony, and lead were the most important metallic impurities in relating the metal to the original type of ore. They used a product function based on the concentrations of these elements as a discriminate function to assign metals to the ore type. For some reason this technique has not been used by archaeometallurgists and geoarchaeologists. The only exception of which I am aware is the study by Agrawal (1971).

"In order to study the effectiveness of this technique, we subjected the analysis of the Chalcolithic samples from India shown in Table 2.1 to discriminate analysis. The study is only partial because the analytical data contain only antimony, arsenic, iron and lead. Friedman *et al.* (1966) indicate that adding silver and bismuth would increase the discriminating power.

"Table 2.3 indicates the results of this study. Even though three of the thirteen results give ambiguous answers, it can be seen that native copper is an unlikely ore source. For the Chalcolithic of India, smelting provided the unalloyed copper.

"The weakness in the method used by Friedman *et al.* (1966) and a general problem with artefact analyses is the lack of analysis for sulphur. With the addition of sulphur and the refinement of the other data, this method should improve discrimination of ore type. (The large database of native copper analyses enables me to refine Friedman's probability tables on native copper.) It should be noted that sulphur can come into a furnace charge through slagging and fluxing components (for example, through jarosite and mixed with goossan limonite) as well as by being part of the ore.

Table 2.3 Discrimination of ore type for Chalcolithic copper artefacts from India

Artifact number	Antimony		Arsenic		Iron		Lead		Relative probability (per cent)			Likely ore source
	ppm	unit	ppm	unit	ppm	unit	ppm	unit	I	II	III	
1	2460	5	20,650	7	25710	7	5340	6	0	6.5	93.5	sulfide
2	351	3	32	1	47.6	2	6.7	1	30.4	12.7	56.9	sulfide
3	34.3	1	4420	6	44.3	2	689	4	0.6	69.3	30.1	oxide
4	42.7	2	6810	6	402	4	365	3	0	46.7	53.3	ambiguous
5	44.5	2	1300	5	289	3	1180	5	0.7	53.6	45.7	ambiguous
6	213	3	24000	7	1360	5	1220	5	0	0.5	99.5	sulfide
7	30	1	1840	5	80	2	6490	6	33.7	28.2	38.1	ambiguous
8	45.7	2	53.3	2	77.7	2	463	4	1.5	78.5	20	oxide
9	45.8	2	490	4	81.2	2	439	4	0.3	70.6	29.1	oxide
10	37.9	1	18400	8	125	3	707	4	0.9	61.6	37.6	oxide
11	22.9	1	641	4	26100	7	3680	5	0.2	36.5	63.3	sulfide
12	39.1	1	1290	5	110	3	3570	5	6.8	55.8	37.3	oxide
13	34.1	1	1610	5	105	3	676	4	1.7	93.3	5	oxide

"Successful use of this method should provide additional help in determining the antiquity of the technology of smelting sulfides. In my opinion, chemical determination of native copper and of ore type is achievable particularly as additional refinements in methodology are made".

ROLES OF ARSENIC, TIN, LEAD, ANTIMONY, AND NICKEL

"Tin is a significant component in a few copper ores (for example, Cornwall, England), but except in rare cases it is unlikely that tin in amounts greater than 0.10% was accidentally incorporated in smelted copper. Tin proportions between 0.10% and perhaps 1.5% or 2.0% most likely result from reuse of scrap metal.

"The most interesting questions involve the early arsenical coppers. Analyses from dozens of early metallurgical centres have shown that arsenic bronzes were fairly common in the Chalcolithic and Early Bronze Age. Coghlan (1972) and others have detailed the important property changes with the addition of varying of alloying arsenic with copper. The use of arsenic was not only widespread, it was also intensive. In a fourth millennium BC Near Eastern hoard of copper objects, twenty-four of thirty-six analyzed had an average arsenic content of 5.23% (Muhly 1977).

"Unlike lead there is no evidence that arsenic was ever used as a metal (and native arsenic is very rare) or found as an ingot (such as copper and tin). Thus arsenic must have been alloyed with copper by the smelting of complex ores containing both copper and arsenic.

"There seems to be a consensus among archaeometallurgists that the first copper minerals smelted were the hydroxycarbonates (malachite and azurite) and the oxides (cuprite and tenorite), yet the first alloys were arsenical. McKerrell and Tylecote (1972) and many others have suggested that the metallic-looking complex copper arsenic sulfide mineral tennantite would come from the lower unoxidized zone (along with many metallic-looking copper sulfides).

"The following arsenates are all associated with malachite in the oxidized zone of copper deposits in Europe, the Near East (including the USSR), and elsewhere:

Olivinite	$\text{Cu}_2(\text{AsO}_4)(\text{OH})$
Clinoclase	$\text{Cu}_3(\text{AsO}_4)(\text{OH})_3$
Tyrolite	$\text{CaCu}_5(\text{AsO}_4)_2(\text{CO}_3)(\text{OH})_4 \cdot 6\text{H}_2\text{O}$
Mimetite	$\text{Pb}_5(\text{AsO}_4)_3\text{Cl}$
Adamite	$\text{Zn}_2(\text{AsO}_4)(\text{OH})$
Erythrite	$\text{Co}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$
Annabergite	$\text{Ni}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$

"Use of the last four could account for the occasional high Pb, Zn, Co, or Ni contents of arsenic bronzes. And oxide copper ores rich in arsenic would lose less arsenic during smelting than the sulfide ores.

"The beginnings of arsenic and copper alloying may well be coincidental, or nearly so, with the beginning of smelting complex sulfide ores. Although others have suggested the tetrahedrite-tennantite series, $(\text{CuFe})_{12}\text{Sb}_4\text{S}_{13}/(\text{CuFe})_{12}\text{As}_4\text{S}_{13}$ as the most likely ore, I believe that enargite (Cu_3AsS_4) is a more likely candidate. Tetrahedrite is much more common than tennantite, and early arsenical coppers usually do not have high concentrations of antimony. Enargite is often found in large quantities and is well known from deposits in Austria, Hungary, and at large deposits at Bor, Yugoslavia (Sillitoe 1983). All these copper ore minerals oxidize to malachite.

"Although there are arsenical tin deposits at Cornwall, in Bolivia, and elsewhere, there is little evidence to indicate the early importance of this type of deposit. Interest in the mineral stannite ($\text{Cu}_2\text{FeSnS}_4$) may be revived with the recent discovery by Yener (1985) of stannite deposits near early metallurgical sites in southern Turkey" (Rapp 1988).

COPPER HOARD COPPER SOURCES

The sources of the Copper Hoards copper have been discussed in chapters 6 and 8.

ORE-ARTEFACT CORRELATION

For ore-artefact correlation Pittioni (1957) had successfully used comparison of trace impurity patterns between ores and artefacts in Austria (Pittioni, R. 1957. *Urzeitler Bergbau auf Kupfer und Spurenanalyse. Archaeologia Austriaca. Beiheft 1*). I had used this technique by comparing a suite of 22 elements for comparing Rajasthan, Bihar ores and Harappan and other protohistoric artefacts (1971). But it has now been found that lead isotope ratios are a better guide. Still better is to use both trace impurity patterns and lead isotopes. In India, Hegde and Ericson (1985: 59-69) made some lead isotope analyses of copper and lead ores in the Aravalli hills of Rajasthan. But the work was not followed up to work out any ore-artefact analyses.

Hegde (1965), however, found 92% agreement between the Chalcolithic artefacts and Rajasthan ores.

Explaining the lead isotope technique, Scaife *et al.* say, "Lead consists of four stable isotopes (^{204}Pb , ^{206}Pb , ^{207}Pb and ^{208}Pb). Three of these have radioactive progenitors the decay of which supplements the original (primeval) ratios. The fourth, ^{204}Pb , is unchanged from its primeval quantity. The proportions of each of these isotopes in an ore body will depend, in the first instance, on two factors: the geological age of the ore body and the relative proportions of primeval lead, uranium and thorium in the ore-forming reservoir. If present, uranium or thorium in the ore body itself will subsequently alter the isotopic composition. As a result of these factors, the lead in an ore body will have a distinctive, though not necessarily unique, range of isotopic

compositions. Although lead consists of four isotopes there are in fact only three variables when considering the isotopic composition. The constraint of the four isotope proportions necessarily summing to 100% means that the abundance of the fourth isotope is always determined by those of the other three. Rather than use three abundance percentages as independent variables, it is conventional and more accurate to use the ratios $^{208}\text{Pb}/^{206}\text{Pb}$, $^{207}\text{Pb}/^{206}\text{Pb}$ and $^{206}\text{Pb}/^{204}\text{Pb}$, since these are measured directly by the thermal ionisation mass spectrometry technique, which is currently used in lead isotope analyses" (Scaife *et al.* 1994: 301-7).

Budd *et al.* are in the forefront of such studies. They have emphasised the pitfalls in any such correlations. They say, "Although most researchers have come to recognise the complexity and limitations of compositional data (see for example Pernicka 1995), Pittioni-style provenance studies continued for decades. Despite Thompson's warning, tens of thousands of prehistoric metal artefacts were subsequently analysed. On a more detailed level, attempts to link compositionally similar artefacts to common geographical sources have almost always proved inconclusive. Artefacts grouped on the basis of composition have often come from unrelated contexts, sometimes widely scattered across vast areas.... When the assumptions which underpin these approaches are examined, it is easy to see the pitfalls. For trace element provenancing to succeed it is necessary to assume that the artefacts under consideration were fabricated using similar manufacturing processes, derived from a strictly limited number of sources and smelted in such a way as to produce a metallic product with a limited range of impurities. Furthermore, one is obliged to make further fundamental assumptions about alloying and recycling. Whereas some copper deposits may contain distinctive traces of particular trace or minor elements, very few have been studied mineralogically to the point where quantitative estimates of different mineral species' contributions to ore 'as-mined in prehistory' can be. Similarly, there is little detailed understanding of the behaviour of impurities in primitive smelting processes. Simple thermodynamic models are problematic and many experimental studies have been little more than imaginative reconstructions of hypothetical processes, sometimes using inappropriate materials and poor control and monitoring" (Budd *et al.* 1996: 168-74).

Alex Haliday & Young have used ICP multi-collector Mass spectroscopy to identify reuse and recycling of bronze. Young & Pollard (1997) have also shown the effective applicability of Pb isotope sourcing in Namibia.

A lot of important papers on archaeometallurgy were presented in a seminar held in 1997 at the Harvard University organised by two most active workers in the field, Suzanne Young and Paul Budd (1999). Relevant extracts from a few papers are given below.

Discussing about the role of arsenic, tin, lead, antimony, and nickel, Rapp says, "As indicated, analyses of Chalcolithic and Early Bronze Age copper-based artefacts show appreciable amounts of arsenic, tin, antimony, and lead, often greater than 1%. Because of lead's low melting point (327°C) and the ease of smelting galena (below 800°C), lead was an easy metal for early metalsmiths to use. Galena deposits are fairly available throughout the areas where metalsmithing originated. The chief question that concerns us is distinguishing lead added deliberately to improve the resulting alloy from lead that entered the metal because it was available as a component in the ore. Until more definitive data can be obtained, at this point, it seems reasonable to use 1% as the demarcation between accidental and deliberate lead values".

Although antimony is present occasionally in early copper-based metals in amounts greater than 1% (thereby having an effect on the properties of the metal), it seems likely that antimony was always an accidental alloying element when it was a component of the sulfide ores. Nickel

presents a greater problem. Chang and Schwitter (1957) have shown that many Syrian, Sumerian, and Indian bronzes contain more than 1% nickel, and some contain more than 3%. They also found that the nickel composition was a function of the type of object, thus indicating deliberate choice. The question remains, how much of the choice was made before smelting and how much was based later on the working characteristics of the products of various smelts? Nickel is present in amounts greater than trace levels (>100 ppm) in many copper-based artefacts from most of the important metalworking regions in the Chalcolithic and Early Bronze Age. Tin is a significant component in a few copper ores (for example, Cornwall, England), but except in rare cases it is unlikely that tin in amounts greater than 0.10% was accidentally incorporated in smelted copper. Tin proportions between 0.10% and perhaps 1.5% or 2.0% most likely result from reuse of scrap metal (Rapp 1988: 21-27).

CHAPTER 3

ARCHAEOMETALLURGICAL TECHNIQUES

CONTENTS

- INTRODUCTION
- METAL PYROTECHNOLOGY IN INDIA
- MAKING OF HARAPPAN ARTEFACTS
- TECHNOLOGY OF THE CHALCOLITHIC CULTURES

INTRODUCTION

In this chapter we will talk about the basic techniques of metal technology and related evidence from archaeological sites. We will first trace the history of pyrotechnology in a global perspective and then discuss the evidence related to South Asian sites.

Darling (in McNeil 1990) has claimed that the earliest crucible furnace remains so far identified were found at Abu Matar, near the old city of Beersheba in Israel at a site dated between 3300 and 3000 BC. These furnaces appear to have had a vertical cylindrical clay shaft, supported in such a way that air could enter freely at the lower end, providing the necessary draught. The earliest furnaces reported from Ahar, Rajasthan, however have provision for bellows.

The earliest copper slags were found at Catal Huyuk, in Anatolia, in a 7000-6000 BC context and the earliest cast native copper from Sialk in Iran (4500 BC). The earliest Egyptian artefacts date from 5000-4000 BC. Darling (1990) therefore suggests that the technique of melting and casting native copper originated in Anatolia between 5000 and 4000 BC. By the end of the fourth millennium BC, the extant supplies of native copper could not meet the rapidly increasing demand. This is obvious from the fact that most of the copper artefacts produced after 3500 BC contain substantial quantities of nickel, arsenic, iron, or other base metal impurities indicating that ores were now being processed to extract copper. Systematic copper mining had begun as early as the first half of the sixth millennium.

In the beginning, copper was extracted from oxide or carbonate ores that could generally be smelted successfully in the primitive furnaces then available. For example, at Rudna Glava in Yugoslavia, a copper working site of 6th millennium BC, the main chalcopryrite ore body was not exploited, but used instead a thin, rich carbonate vein. But by about 1000 BC, smelting techniques reached their zenith at Timna. The rings and other small artefacts of iron found at Timna are now thought to have been the by-products of the main copper refining operations. Lead isotope 'finger-printing' has shown that the source of the iron was the hematite used to flux the copper ore during refining (Darling 1990).

As we will discuss later in the Indian context too, the presence of arsenic and other elements did not always indicate a deliberate alloying but only the fact that now they were using ores to extract copper and not native copper or oxide minerals. Darling also (1990) states, "From the presence of arsenic and other impurities in many of the early Copper Age artefacts it must be concluded that much of the copper used was extracted from sulphide rather than oxide or carbonate ores. In prehistory, as in modern times, the bulk of the world's supply of copper appears to have been obtained from ores based on chalcopyrite, a mixed sulphide containing equi-atomic proportions of iron and copper".

The sulphide copper ores exploited at the beginning of the Copper Age appear to have been located some distance below the surface of a weathered and oxidised primary outcrop. The iron-oxide regions above rich copper deposits are known as gossans. From these gossans, when copper content is completely leached away, it is precipitated in sulphide form in the surrounding strata. This is how secondary enrichment of copper minerals is effected.

Darling (1990: 71) has described in detail the extraction of ores at Laurion in the fourth and fifth centuries BC. The ore "was crushed with iron mallets and then ground to a sandy consistency in rotating stone hourglass mills or in hopper querns. The crushed ore emerged as a fine powder from which the lighter, earthy material was removed by water washing in some very ingenious helicoidal washers. A continuous current of water during its passage around the spiral, carried the suspended particles of ore from cup to cup and classified them. The rich ore was the first to be deposited, then the poorer ore and finally the sand and silts. When the water reached the lower tank all suspended solids had been deposited and it could be returned to stand tank, so completing the circulation process".

Darling (1990) has traced the history of global metallurgy as follows: By the early third millennium, foundry processes in the Land of Sumer appear to have developed rapidly. Before 3000 BC most of the copper artefacts from Ur were simply fabricated from sheet metal. By 2700 BC, however, very refined cast copper artefacts were being produced, probably by a version of shell moulding, using a prefired mould of thin clay. Long thin sections, such as the blades of swords and daggers, were also cast into thin shell moulds, which appear to have been heated to redness before the molten metal was introduced. By 2500 BC, the Egyptians had developed considerable expertise in the production of hollow copper and bronze statuary. Many large Egyptians statues were cast with an internal sand core, which is still present in some of the figures which have been found. Smaller components, such as the spouts of copper water vessels, were undoubtedly made by the *cire perdue* ('lost wax') technique, which had obviously been mastered by Egyptian craftsmen before 2200 BC.

The characteristic metal artefact of Crete was the double axe, an object of great ritual significance; the compositions of some of which range from pure copper to ductile 4 per cent tin bronzes, and finally to hard, brittle bronzes containing 18 per cent tin. By early second millennium BC, Crete was beginning to obtain tin from Eritrea and southern Spain, and their designs for spearheads and daggers were widely copied throughout the ancient world.

The Dorians had primitive metal working skill of their own. It was the combination of Dorian vigour and Minoan sophistication, which eventually emerged as the metallurgical virtuosity of classical Greece. Bronze statuary soon began to demonstrate a mastery of foundry techniques which remained unsurpassed until the European Renaissance. Such casting probably represents the high peak of Bronze Age technology, preceding the later domination by Rome of the classical world.

Before 500 BC, bronze technology had developed in an irregular manner which does not relate in any metallurgical sense with the Early, Middle and Late Bronze Age classifications of the archaeologist. The major metallurgical discontinuity occurred around 1600 BC, in late Minoan times, when large copper ingots weighing more than 30 kg first appeared, and the usage of bronze throughout Europe and the Mediterranean region began to increase very rapidly.

The full Bronze Age emerged in the middle of the second millennium BC. After about 1600 BC, the majority of the bronzes produced contained lead, which, in most cast objects of any intricacy, was present in concentrations between 5 and 10 per cent by weight, and which was added to improve casting fluidity.

The Shang bronzes, produced at Anyang between 1400 and 1027 BC, are now world famous for their artistic merit and technical virtuosity. These ritual objects, which were produced entirely by casting, were notable for the richness of their relief patterns and also for their mass and solidity, although some smaller wine vessels were also produced. One vessel weighed over 1.6 tonnes and had obviously been cast in a multipart mould made from prefired clay segments. Most of these Shang artefacts had lead contents less than 1 per cent by weight, and some contain negligible quantities of lead. It would appear lead was an accidental impurity. The tin content of the alloys varies considerably, however, in what appears to be a random manner from about 1.8 per cent to more than 20 per cent.

To produce large, intricate and decorative castings which would not be subjected to mechanical shocks, the Chinese preferred to add lead to obtain the casting fluidity required. To avoid brittleness in weapons, the tin content was very considerably reduced and a minimal quantity of lead added to improve the castability of the alloy. The melting point of a binary 20 per cent tin bronze is approximately 880°C; a similar quantity of lead only reduces the melting point of copper to 1000°C. The high tin, lead-free alloys would therefore be easier to melt and cast in large quantities and this must have been a factor which encouraged their use in a situation where tin was plentiful and intricate castings weighing perhaps a tonne were being produced. (We will discuss Chinese metallurgy in detail in chapter 10).

Bronzes containing 20 per cent tin are invariably associated with the manufacture of bells. It is interesting to note that the Greeks attempted to standardise the compositions and mechanical properties of bronzes around 360 BC. They specified that the contractor will use for the blocks copper from Marion, the alloy being made of twelve parts, eleven of copper to one of tin. This Eleusinian inscription apparently provides the earliest evidence for the use of a metal turning lathe in the Greek mainland.

The main Roman metallurgical innovation was the introduction of brass which was first used for coinage when tin became expensive. Romans worked the Tartessian mines continuously from about 200 BC until AD 400. The mines appear to have reached their maximum output between the second and third centuries AD. The ancient Roman workings at Rio Tinto were not reopened until the middle of the 16th century, during the reign of Philip II.

Romans exploited the copper mines of Tinna in the Negev only in the third century AD, although workings continued until the middle of the seventh century when the Arabs invaded.

Most of the statuary of the Graeco-Roman world was cast in bronze. Lead-tin bronzes were generally used in the fourth century Greece, although zinc was also added to the later Roman bronzes, which by the middle of the second century AD tended to contain comparable quantities of zinc and tin.

The arsenical content of Middle Eastern copper artefacts begins to decline after about 3000

BC, perhaps due to the progressive exhaustion of rich, accessible arsenical copper ore deposits. Artefacts containing less than 2.5% tin made their first appearance during the early stages of this decline. Such tin bronzes, which first appeared in Iran around 3000 BC, did not reach England and Brittany, until about 2200 BC. Such low tin bronzes must be regarded as the precursors of the later true bronzes containing 8-10 per cent of tin. These bronzes were made either by the smelting of copper ores which contained tin minerals, or by the use of tin-bearing fluxes.

Darling (1990) emphasises that no evidence for a gradual evolutionary process has been found, and virtually no artefacts containing more than 2.5 per cent of tin have been identified which antedate the sudden emergence of the 8-10 per cent tin in Sumerian bronzes between 3000 and 2500 BC. Perhaps the copper-smiths of Ur suddenly discovered the concept of alloying, and rapidly developed and optimised the composition of bronze. This technological innovation is associated with the rapid expansion of trade in West Asia around 3000 BC.

Muhly (1980) also describes the differing patterns of alloying in different regions, "The great advance in copper metallurgy was the widespread use of copper alloys, in both arsenic and tin. The distribution was complicated, with some areas (*e.g.* Crete) favouring arsenical bronze while others, such as the Troad, were partial to tin bronze and still others, notably central Anatolia, made equal use of both at the same time. The situation in Egypt is rather unusual in that tin bronze was virtually unknown while elaborate use was made of additive arsenic. Taking advantage of arsenic's tendency to segregate at the surface and form a silvery outer layer that could be polished, the Egyptians produced a series of mirrors with a silvered reflecting surface. This silvery surface was also known in Anatolia and can be seen on several copper bulls from the site of Horoztepe, as shown by the work of Cyril Smith. The Egyptians apparently even used this technique, or that of vapour plating as on the bulls, to plate a spouted copper ewer, if that is the correct interpretation of an object in the Metropolitan Museum described in the literature as being plated with antimony. Nor is plating the correct descriptive term for what was actually an enrichment by surface segregation".

The most abundant and significant tin mineral is cassiterite, the oxide SnO_2 , which varies in colour from brown to black. Cassiterite is noteworthy in that its high specific gravity of 7.1 is comparable to that of metallic iron, and also because its hardness is comparable to that of quartz, so that it is highly resistant to abrasion and tends to concentrate in gravel and alluvial deposits.

Four cassiterite mines have been located in the eastern Egyptian desert, one of which was accurately dated from inscriptions associated with the Pharaoh Pepi II to around 2300 BC, approximately 500 years after the appearance of the first Sumerian bronze. Copper artefacts, containing significant quantities of tin were not produced in Egypt before the Fourth Dynasty, around 2600 BC, and the true Bronze Age in Egypt, when artefacts containing 8-10 per cent of tin were produced, did not begin until 2000 BC.

It seems logical to assume that at some time around 3000 BC, the concept of bronze manufacture was acquired by the Sumerians, either by trade or conquest, from a region outside Mesopotamia where tin was a readily available commodity.

Between 2600 and 2500 BC, supplies of tin to Mesopotamia appear to have been interrupted, many of the copper artefacts dating from the Second Sumerian Revival being simple arsenical copper containing little or no tin.

The shortage of tin, whether it was caused by natural disasters or by political upheavals, was not prolonged, however, and after about 2500 BC the use of 8-10 per cent tin bronzes

expanded rapidly throughout the Middle Eastern world.

Early Bronze Age developments have also been found in southern China, Thailand and Indonesia, where alluvial tin and copper ores are sometimes found in close association.

It probably arrived with the peaceful integration of a group of skilled foreign workers, perhaps displaced by military disturbances in China. Chinese bronzes containing 8 per cent of tin were being produced in Gansu province as early as 2800 BC, apparently independently of the emergence of high tin bronzes in Sumer.

The earliest tin bronzes so far identified appear to date from the fourth millennium BC and were found in 1930 at the site of Tepe Giyan, near Nahavand in Western Iran.

The sudden appearance of true bronzes at Ur around 2800 BC, and in Amuq near Antioch in Turkey, about 3000 BC would be consistent with the view that the concept of bronze manufacture originated in a community such as Tepe Giyan, in the Persian highlands, during the 4th millennium, who subsequently moved southwards to Sumerian and the Persian Gulf, and westwards to the Mediterranean seaboard, during the third millennium.

Bronze was first made in Italy between 1900 and 1800 BC, using tin from deposits at Campiglia Marittima in Tuscany, although copper extraction started in Spain in Neolithic times and during the third millennium its copper and precious metal deposits were extensively worked.

Many crucibles used in the Mediterranean region between 3000 and 2500 BC had to facilitate handling socketed boss moulded on one side.

Although lead was also known at a very early date, the first metal to be practically utilised was copper. Small beads and pins of hammered copper found at Ali Kosh in Western Iran and Cayonu Tepesi in Anatolia date from the period between the 9th and 7th millennia BC and were made from native, unmelted copper.

The native copper which is still abundantly available in the vicinity of the Lake Superior deposits in North America, was worked from 3000 BC until shortly after the arrival of the Spanish invaders.

The implements and weapons produced in North America from native copper all appear to have been produced by cold forging with frequent annealing at temperatures below 800°C copper.

With this background of the global history of metallurgy, we now turn to the Indian pyrotechnology.

METAL PYROTECHNOLOGY IN INDIA

We will first discuss the Indus evidence as we have the maximum information on it compared to other cultures.

Harappan Pyrotechnology

In connection with her dissertation, Heather Miller has specialised on pyrotechnology. As this is the only exhaustive and specialised study of Harappan pyrotechnology, we have made liberal use of her work here. The following discussion on pyrotechnology is mainly based on Miller (1993) and Kenoyer & Miller (1999), and also on Agrawal (1971), Chakrabarti and Lahiri (1996), Hegde and Ericson (1985) (see also Jarrige 1985b; Kenoyer 1997a, 1998; Miller 1994a,b, 1997a, 1998).

Earlier workers often did not distinguish between melting and smelting (reduction of ores

to metal) evidence nor between kilns and furnaces. Recent work by Miller, under HARP (Harappa Archaeology Research Project), has done a great deal in sorting out such confusions which are not merely semantic but signify important metallurgical processes. As HARP is well equipped both equipment-wise and human resources-wise we will mainly base our account on their work at Harappa site. In recent years, the most focussed study on the Harappan pyrotechnological remains has been carried out by Miller (1993). As she critically reviews the previous work too, we will first discuss her publications, then go to other sources of information.

At the outset, Kenoyer & Miller (1999) caution about the use of terms: "...we prefer the more general term 'kiln' rather than using 'furnace', a term specific to metal processing".

The major indicators for metal processing at a site are defined by Kenoyer & Miller (1999) to include: (1) fragments of ores; (2) kilns, or fragments of kilns, attributed to metal processing; (3) metallurgical slag, from the reduction of ore to metal; (4) tools used for metal processing, such as crucible fragments with metal prills, moulds, anvils, stakes, hammers, chisels, etc.; and (5) metal objects, including smelting and melting ingots, semi-finished and finished objects. Significant amounts of ores and/or metallurgical slag fragments are the most convincing evidence for smelting at a site. A variety of clay-based non-metallurgical slags, including fragments of kilns and crucibles, can represent either the smelting of ores or the melting of metal, depending on the exact nature of these indicators (Bayley 1989; Craddock 1989; Miller 1994b). Metal-working tools (other than crucibles with prills or moulds) are usually difficult to attribute directly to metal processing, except when found in well-documented contexts in association with a number of other metal-working indicators. Metal objects, including metal ingots, must also be from such contexts to show their production at a site, as these objects may have been imported from other sites.

Kenoyer & Miller (1999) say, "... by the 4th and 3rd millennia it is clear that mining and smelting of ores was being carried out in many localities throughout Baluchistan and Afghanistan (Dales and Flam 1969, Fairervis 1952, 1961, Jarrige and Tosi 1981, Stech and Pigott 1986). Smelting of metal ore usually results in fairly conspicuous accumulations of manufacturing debris and broken furnaces. In particular, the smelting of most ores results in the production of weather-resistant metallurgical slags, vitrified masses of silica and other fused minerals which generally accumulate in conspicuous mounds near the smelting furnaces. On the basis of quantity and type of slag, the small amounts of copper metal slag found at Indus Valley Tradition sites seem to be more representative of melting rather than smelting (Miller 1994b). The often cited copper smelting slags from Ahar are from levels dated to the second millennium BC, after the end of the Harappan Phase. The absence of slag heaps and smelting debris may be due to the fact that most excavated sites, particularly of the Harappan Phase, are located some distance from the primary sources of metal ores. Further collections and analyses are needed in the Aravallis, as well as in the regions of Gardan-i-Reg and Cholistan, to determine if there are Indus Valley Tradition or contemporaneous smelting sites in these regions. Archaeologists working in Rajasthan have made a laudable effort to look for copper slags, but specialist surveys are needed".

Discussing the available evidence, Kenoyer & Miller concur with Sana Ullah's (1931: 485) and Mackay's (1938: 451) earlier interpretations that most of the copper used at the Harappan Phase sites was imported in ingot form, and little or no smelting was done at the major sites of the Indus Valley Tradition. Plano-convex disc-shaped ingots (almost all of copper) have been recovered from Chanhudaro (Mackay 1943: 188), Lothal (Rao 1979), Harappa (not reported but found in the reserve collections) and Mohenjodaro (Sana Ullah 1931: 485; Mackay 1938: 451). Although relatively few ingots were reported in these publications, recent examination by

Kenoyer of the reserve collections from Harappa, Mohenjodaro, and Chanhudaro (Museum of Fine Arts, Boston) have revealed the presence of additional examples.

Kenoyer & Miller (1999) argue that the melting of metal is a necessary stage in the production of cast objects, both semi-finished and finished. "The remelting of original smelting ingots to produce secondary or refined ingots is also a common intermediary stage between the production of the original smelting ingot and the final fabricated or cast object. This secondary ingot production is undertaken for one or more reasons: to remove slaggy impurities left in the original smelting ingots; to break up large smelting ingots into more workable or transportable ingots; to form metal alloys; and/or to melt down metal scrap, which is usually varied in composition.... For example, Sana Ullah remarked in the very first published analysis of Harappan Phase ingots (his 'copper lumps'), that three of the four ingots were the 'crude product of the smelting furnace' which were too rich in sulphur to be forged. He suggested that such ingots would be remelted for refining; otherwise this metal could only be used for casting 'heavy or plain objects' (Sana Ullah 1931: 484-85)".

Kenoyer & Miller (1999) warn that... "much of the archaeological evidence for melting (and casting) resembles the evidence for smelting, i.e., the presence of crucibles, kilns, slag, and metal ingots. However, careful analysis of these objects, particularly identification of the types of slags present, usually allows differentiation of these processes".

I think Rakhigarhi and Ganeshwar complex sites need to be explored for such copper ingots which have been reported at the Harappan sites.

Crucibles: Kenoyer & Miller note that the evidence for melting of copper in crucibles is first found during Period III at Mehrgarh, dated to 4000-3500 BC. Crucibles with traces of melted copper have been found in rubble associated with a Period III firing structure made of brick (Jarrige 1983, 1985a). Jarrige notes that the crucibles are comparable in interior size and shape to the ingot recovered from Lothal (1985a: 289). Only a few crucible fragments with copper prills have been reported from the Harappan Phase sites, although they could represent small-scale smelting of high-quality copper. A crucible rim fragment was found during excavations at Mohenjodaro, and Sana Ullah gives the opinion that it represents the re-melting of crude metal for refining (1931: 485 and Plate CXLII,9). No analyses were ever published, but the photograph of this rim shows slagging, and looks quite similar to fragments found by the Aachen/IsMEO surveys at Mohenjodaro. A single crucible is also reported from the excavations at Harappa; Vats mentions in a footnote that "a fragmentary earthenware crucible whose contents show that it was used for melting bronze" was found near furnace "Fa" on Mound F at Harappa (1940: 471). Again, no analyses were ever published. Finally, the so-called "crucibles" reported from Lothal must be some other kind of container, as they had no traces of slagging and upon analysis contained no trace of copper (Lal 1985: 661). At Harappa, half a dozen crucible rim fragments with slagging and copper prills have been found in surface surveys of the southern slope of E Mound, and a number of both rim and base fragments of similarly slagged crucibles have been found in nearby excavations (Miller 1994a, 1994b). At least two crucible fragments with slagging and copper prills were also found in surface surveys at Mohenjodaro, as well as an entire small ceramic cup (Pracchia *et al.* 1985; Tosi *et al.* 1984). This cup is similar to the crucibles used by modern goldsmiths in South Asia, but there are no visible traces of metal or slagging, and microprobe analyses found no traces of metal (Vidale: personal communication). All of the crucible fragments from Harappa, and one of the two from Mohenjodaro, show a quite small diameter; the second fragment from Mohenjodaro is much larger. Based on the associated types of slags, these seem

to represent melting crucibles, not smelting crucibles, but archaeometric research still has to be done.

Of the five crucibles/muffles, three were found together, and are also of the same shape and size, with a smooth interior and rough exterior, and heavily fired apparently more than once (Mackay 1938: 178, Pls. XLI, 72; LXVI, 14). Another piece is thickly coated with a mixture of sand and clay, and seems to have been expressly constructed to withstand heat. However, it is only in the case of the last specimen that one can be sure of its being used for copper-smelting/melting since there was slag on its edges (Pl. CXLII, 9). Unfinished and unworked objects: two lumps of sulphur-rich crude copper and two lumps of very pure copper (Marshall 1931: 485), rough castings including those of jar-handle, two indeterminate objects and four ingots were all found in the area of room 15, house IV, block 12A; house 1, room 15 (DK Area). Room 52, house VI, block 1 of the same area yielded two castings of blade-axes. A few miscellaneous fragments including two small rods were found in the same context. Furnaces and metalworking areas: three ingots were found in "room 15 of house IV, block 2, evidently the quarters or workshop of a metalworker, at levels ranging from 14.5 to 11.1 ft. The rounded lower surface of each is comparatively smooth as though the hole into which the flows were run had been shaped about the curved base of a jar". Two kilns were noted close by. Measuring 3 ft 3 inches in diameter at the top and 4 ft and 3 inches in depth, the inside surface of the mudlined pits was vitrified. Each had a 4-inch wide ledge inside, possibly intended for a grate. There was no draught or vent in their lower portions, and according to Mackay this could act against the premise of there being copper-smelting places. Two other kilns were noted in different locality, the larger one belonging to the Late I a period. A rectangular brick-lined pit (5 ft 6 inches by 4 ft 3 inches and 4 ft 6 inches deep) could have been used by a metalsmith since copper ore and lead were found there (Mackay 1938: 54). It is also possible that the assorted objects (copper and bronze axes, ingots, castings, etc.) found in House I in Block 12A suggest the presence of metalworkers.

Kilns: Kenoyer & Miller (1999) have critically examined the reported evidence of kilns and report that not all were really kilns for copper smelting/melting. Kenoyer & Miller (1999) report four kilns at Harappan Phase sites which have been attributed to copper-processing: one at Harappa (Vats 1940: 470-73, Fig. d, Pl. XVIa and b); one at Lothal (Rao 1979: 522), and two at Mohenjodaro (Mackay 1938: 49-50, 452). In all of these kilns, the interior is heavily vitrified, and the blackened melted surface indicates a reducing atmosphere. This evidence of high temperatures seems to have been the primary reason for attributing these kilns to metal processing. They point out that evidence of high heat alone is not sufficient to show that a kiln was used for metal processing. Many of the excavated Indus Valley Tradition pottery kilns show similar vitrification (*e.g.*, Dales and Kenoyer 1989), as did experimental mud-brick pottery kilns fired at Harappa during the past seven seasons. The temperature data obtained during the experimental firings show that the vitrification of the ceramics and the walls of the kiln occurred somewhere in the range of 1000° to 1100°C, generally in a heavily reducing atmosphere (Meadow and Kenoyer 1992; Kenoyer 1994). Kiln "Fa" at Harappa was one of 16 pyrotechnological structures excavated by Vats in a relatively small area of Mound F. Kenoyer & Miller (1999) emphasise that this kiln was the only one of the 16, Vats ever suggested might be related to metal processing. When first excavated, half of the original structure was present (split vertically), and the interior was well-preserved due to heavy vitrification. The kiln is described by Vats as a pit 3 ft 4 in (1 m) in diameter and 3 ft 8 in (1.1 m) to 5 ft 3 in (1.6 m) deep. The interior was covered

with a sand-tempered mud plaster (Vats 1940), and recent observations reveal that it was at least partly constructed with mud brick (Miller in Meadow and Kenoyer 1992). Vats found evidence for a vaulted roof with four "flues" remaining, and a fifth "flue" entering at a slightly lower level. Using a modern Punjabi metal melting furnace as a parallel, Vats proposed that the latter flue was used as an air channel worked by bellows from above (Vats 1940: 471). Kenoyer & Miller (1999) further suggested that the roof flues were intended as outlets for smoke and/or inlets for fuel which could be closed during operation. No copper prills or copper slags were found in Vats' original excavations or in subsequent surface surveys by the HARP team (Dales and Kenoyer 1990 and Miller in Meadow and Kenoyer 1992). Consequently, upon closer examination there is no evidence to support the implication that kiln "Fa" was used for metal processing. The circular kiln at Lothal was 6 ft (1.8 m) in diameter, 2 ft 3 in (0.7 m) deep, and made of mud brick with mud plaster. The use of this kiln for melting copper ingots was attributed from its location near the so-called "coppersmith's workshop" (Rao 1979: 522). However, the kiln itself showed no signs of copper melting. Indeed, most of the evidence for use of this area for copper melting has been refuted: the analyzed terracotta crucibles/moulds show no signs of copper or other metals; the "slag" turned out to be corroded copper metal; and the "stone moulds" for casting are more likely to be for grinding of stone beads or other materials. At present there is no published evidence for copper melting at Lothal. The two kilns at Mohenjodaro were approximately the same depth and diameter at the top, but varied in size at the base: 4 ft 3 in (1.3 m) deep, 3 ft 3 in (1.0 m) in diameter at the top, and 2 ft 10 in and 3 ft 2 in (0.9 m and 1.0 m) in diameter at the base (Mackay 1938: 49). They were paved with wedge-shaped brick and covered with mud-plaster, with a 4-inch (10 cm) wide ledge on the inside (at different heights), perhaps to support a crucible or grating (Mackay 1938). The interior walls of these kilns were highly vitrified, but again there are no mentions of metal slag, prills, or crucibles associated with these kilns. Mackay himself expresses the opinion that these kilns from Mohenjodaro were used for "something more fusible than copper, owing to the lack of a draught or vent in their lower portions" (1938: 50). Although in another section he contradicts himself, saying that the furnaces were for copper working, based on the find of three discarded copper/bronze castings in a nearby area (1938: 452). But in later writings Mackay (1948: 94) states firmly that there are no known copper smelting kilns from Mohenjodaro. Kenoyer & Miller (1999) also discuss the "circular furnace pit, 1.5 m in diameter and about 0.6 m deep, full of white ashes and metal-worker's slag (Pl. IX, Fig. 3)" from Ahar, according to Misra (1969: 300). Misra reports that this pit was found in the lowermost level of the site, just above virgin soil. However, Kenoyer & Miller (1999) were unable to find any mention of such a pit in the Ahar site report (Sankalia *et al.* 1969), and the only slags mentioned in that report are from Phase IB and IC levels (second millennium BC levels) — no slags are reported from the Phase IA levels, tentatively thought to be contemporaneous with the end of the Harappan Phase. In any case, such a pit is very large for a furnace, and as no signs of burning are noted, it probably represents just a dump.

Summarising the evidence, Kenoyer & Miller (1999) say that based on the published data, there are no known metal processing kilns from any Harappan Phase sites, contrary to secondary sources claiming copper smelting furnaces at Harappa. However, new research is beginning to produce the types of data needed to define the presence of copper processing kilns. For example, many kiln-wall fragments with embedded copper prills have been found on the southern slope of Mound E at Harappa (Miller 1994a, 1994b), and M. Vidale reports the discovery of a small

circular kiln on the surface of Mohenjodaro between VS and Moneer Areas (personal communication). This kiln was approximately 0.8 to 1 m in diameter and was surrounded by hundreds of copper prills and over-fired pieces of clay with copper traces.

About Mohenjodaro, Chakrabarti and Lahiri (1996) also concur, "The evidence of smelting and manufacturing... seems to have been primarily related to secondary manufacture. Admittedly, a quantity of copper ore in pieces, along with a small piece of lead, has been found near a rectangular pit which could have been used for smelting (Mackay 1938: 54). The analysis by C.H. Desch of a copper ore sample (Marshall 1931: 600) suggested 'copper oxide, no doubt a surface ore at the outcrop of pyrites, as it contains some sulphide'. However, this evidence does not amount to much and, in fact, the original excavation reports do not mention artefactual remains which can be interpreted as evidence of primary smelting. Subsequently, despite a careful search, only small surface clusters of metalworking have been documented at the site".

Slag: Kenoyer & Miller emphasise that there is no mention of metal processing slag from any of the early excavations at Harappa or Mohenjodaro. They clarify that from Lothal, several objects originally identified as copper slag have been analyzed and were found to be lumps of corroded copper metal (Lal 1985: 659-61). It is interesting to note that Lal (1985: 658) reports two unshaped objects from Lothal (no information is given about the archaeological contexts or phases of these objects, however, so it is not clear if they are even from the Harappan Phase) composed primarily of iron and copper:

15211 (Lump)	15212 (Cu frag.)
% Cu 43.1	9.3
% Fe 39.1	66.1
% Sn —	—
% Pb —	—
% Ni 1.5	tr
% Zn —	—
% Ag —	—
% Acid	
Insol. 11.5	17.2
% O by	
diff. 4.8	7.04
Total % 100	100

Bisht mentions "a few contiguous rooms" with reddened floors, "several hearths, ovens and fire-pits," and "pieces of copper and copper slags" (Bisht 1984: 90-91), and concludes that this area was probably used by metalsmiths. If subsequent analyses show that these are indeed copper slags, Kenoyer & Miller caution, this information from Banawali will make a welcome addition to the scanty information on metal processing, especially as these rooms are attributed to the Sothi or pre-Harappan (Kalibangan I) levels of Banawali (Bisht 1984: 90).

Miller says that with the crucible fragments, several discrete scatters of metal processing slags have been found during surveys at Harappa (Miller 1994a, 1994b) and Mohenjodaro. (Pracchia *et al.* 1985; Tosi *et al.* 1984). Pracchia *et al.* (1985: 229) report that in Mohenjodaro, "The site was identified on an isolated hillock about 10 m long on the E-W axis and 1.5 m high, aligned with the row of possible workshops detected on the southern flank of HR East, perhaps

along the edge of a single mudbrick structure. Here scattered on an area of 4-5 sq m, we detected a small cluster of bronze-smelting wasters including some fragments of the furnace's walls, a bronze slag, some prills and a single perforated cylinder of copper" (Pracchia *et al.* 1985: 229). These slags are primarily vitrified clay-based materials with copper prills; metallurgical slags are quite limited in number and do not appear to constitute the type or quantity of slag associated with smelting (Miller 1994a, 1994b). Based on both the characteristics of these slags, as well as the relatively small amount of copper slag found at the excavated Harappan Phase sites, they are more likely to be by-products from the re-processing of copper ingots or scraps than from the original smelting of ores.

We will now discuss site-wise details of evidence of metal technology from the Harappan sites.

Harappa

In earlier excavations, some 16 kilns were found but no analyses of the material were ever published. After extensive re-examination of this kiln, in conjunction with conservation efforts over the past two seasons at Harappa, Miller concludes that there is absolutely no evidence that this kiln was used for any kind of metal-working, although it definitely was employed for the generation of high heat. "Fa" was the only kiln Vats ever claimed was used for metal processing of the 16 kilns on Mound F (Vats 1940, I: chapter 18). Thus, contrary to widely disseminated literature, particularly secondary sources, there are no excavated metal processing kilns from Harappa.

Miller (1998) says that though there is no evidence for copper smelting at Harappa, there is considerable evidence for copper melting. She suggests that melting could have been done either for the purification of ingots, the remelting of scrap metal, the manufacture of alloys, and/or the casting of smaller ingots or object blanks. It appears that copper working was the most localised of the crafts at Harappa as almost all of this evidence comes from the centre of the south side of Mound E. She, however, mentions that only two other areas contained more than a single copper-related slag fragment, and each contained only two clay fragments with copper prills. One of these areas (Lot 6063) is on the Southeast corner of Mound E, and HARP excavations (1993) of the perimeter wall just south of this corner yielded a number of copper-related slags in debris layers eroded from the mound; the other area (Lots 6087 and 6004-North) is on the southern slope of Mound AB. Miller admits that at this point it is difficult to say if either of these two areas represent deeply buried melting furnaces, or are related to copper fabrication/casting alone, or represent just the debris from the south-central Mound E area.

During Vats' excavations of Trench IV on Mound E, twenty feet south of Furnace Fa, one of the only copper-related crucible fragments found outside of the south-central Mound E area was found. Vats refers to it as "a fragmentary earthenware crucible whose contents show that it was used for melting bronze" (Vats 1940: 471, footnote 1). But no photographs, drawings, or analytical results are given for this object. It may have been used for melting copper on a very small scale, or even for another industry (such as copper colorants in blue-green faience manufacture). Vats mentions no other evidence for copper working, and Miller's surveys of the nearby area and Vats' back-dirt piles yielded no copper-related slags.

Miller says that there was clearly a great deal of copper processing done in the south-central portion of Mound E, though copper melting appears to have been so localised. A large number of slags with copper prills have been found both by surveys and excavations, most of which seem to be fragments of firing structures, but also include crucible rims and bases, and a few

“true” copper slags (Miller 1994b; Kenoyer & Miller 1999). However, all of this evidence is from surveys carried out in 1990, 1993, 1994 and 1995, and from HARP excavated material (1993) eroded into trenches on flats below the mound. So far none of the actual copper working areas have been excavated. Therefore, Miller finds it difficult to determine whether these data represent a large operation, with many furnaces operating at once, or a smaller operation with fewer furnaces shifting in space over a longer period of time. They propose to make use of Pracchia *et al.* (1985) work on the pottery kilns at Lal Shah, which appears to be a good model for the excavation to be carried to resolve this issue.

Miller reports that many of the furnace fragments have large chunks of copper metal attached to them. As these metalsmiths did not bother to collect even large prills of copper metal from their crucibles or furnaces, Miller correctly infers that it is an indication that they had access to an abundance of copper. I think it also shows that copper was not an imported costly commodity but a local product.

Given the apparent interest of the Indus people in using a variety of materials to create objects of similar appearance (Vidale & Miller 1999), as well as the historically documented prevalence of multi-metal alloys in south Asia (Chakrabarti & Lahiri 1996; Kuppuram 1989), one might expect to see a wide variety of alloys used to create gold-coloured or silver-coloured objects from other metals. The process of alloying may also have taken place in these melting furnaces on the south side of Mound E.

Mohenjodaro

About Mohenjodaro, Miller (1993) reports that while ingots, mis-casts, semi-finished objects and metal fragments from various excavation areas are listed in Marshall (1931: 485), the only non-metal evidence for metal processing from Marshall's excavations is a single fragment of crucible with adhering slag – “unprovenienced and unnumbered” (Marshall 1931: 485).

Discussing Mackay's reports (1937-38) Miller says that most of Mackay's data are also end-products scattered in different areas but predominantly found in DK Area G. The presence of copper ore from a house in DK area is often quoted as evidence for smelting. Miller clarifies that the most important concentration of metal processing remains is in block 1, house 6 (Mackay 1937-38, I: 41), although there were also 3 ingots from block 2 (Mackay 1937-38, I: 451). The block 1 finds include 3 mis-cast copper objects; two vitrified kilns; and a rectangular pit containing a quantity of copper ore in small pieces and a small piece of lead (Mackay 1937-38, I: 452, 49-50, 54, successively). The mis-casts and the pit with ore are both from room 51, but the two kilns were in room 33. Miller clarifies that these are not contemporaneous finds, but are from two different periods. The pit is from Intermediate I phase, when rooms 51 and 52 were one room; the mis-casts and the two kilns are from Intermediate II phase.

Thus, Miller explains that none of these finds are from the same temporal and spatial context. Additionally, there is no evidence that the two kilns were used for metal processing, and after an initial suggestion (Mackay 1937-38, I: 452), Mackay himself states quite firmly that they were not for metal processing (Mackay 1937-38, I: 41, 50), and that there are no metal processing furnaces from Mohenjodaro (Mackay 1948). Summing up Miller says that we are left with a ‘quantity’ of copper mineral and no evidence for smelting it. Thus the ingots, mis-casts and semi-finished objects indicate that copper-alloy processing was done at Mohenjodaro at least fabrication, and probably melting. But so far we do not know exactly where.

Critically analysing the published claims for copper-alloy metal processing areas at Mohenjodaro

and Harappa, Miller says that two do not represent metal processing at all, and two represent melting of copper-alloys, or possibly small-scale crucible smelting (at Mohenjodaro). Miller declares that there is no evidence for large scale furnace smelting at either site, though much of the literature implies or states that smelting of copper took place at Mohenjodaro and Harappa.

Miller further explains why she found the presence of ores in habitation sites surprising and rather unlikely, given the distance from any ore source. If the assemblages from Mohenjodaro or Harappa were indeed from smelting, this would be a very exciting find, because bringing ores to such a distance to be smelted offers tantalising hints about control of production, control of technological knowledge, the status and power of metalsmiths, and/or the sophistication of Indus tradition metal processing in comparison to that of groups living nearer the ore sources.

Miller laments, and we all agree, that the technology of metal processing, in all stages, remains one of the least explored of the major Indus tradition technologies. In archaeometallurgy in general, fieldwork (as opposed to lab work) has often been focused on the large scale reduction of ores to metal-smelting. Less attention has been paid to melting and fabrication field sites, which are admittedly much less visible. At least at Harappa, it looks as if we will have the opportunity to investigate such a melting site. In addition, there are hints that there may also be small-scale crucible smelting of high grade ores at Mohenjodaro, which would be quite exciting as few such sites have been investigated.

MAKING OF HARAPPAN ARTEFACTS

The production of metal objects can be divided into two categories, casting and fabrication, depending on the state of the metal during the actual working. Casting is done when the metal is molten and fabrication is undertaken when the metal is not molten. These two categories divide the methodologies of metal-working artisans as well as the states of the metal itself. Fabrication involves the direct shaping of metal, while casting begins with the shaping of other materials into which the molten metal is poured (Kenoyer & Miller 1999).

The tools and techniques of the two categories overlap to some degree, and ancient metalworking ateliers may have been involved in both fabrication and casting. Some objects, however, may have been cast by one group of artisans and finished or fabricated by another group in a separate workshop. The possible division of manufacturing stages into discrete and often exclusive activities practised by different artisans is an important part of metal working that has not been investigated for the Indus Valley Tradition, primarily because metal production areas have not yet been conclusively identified.

The following discussion of the Harappan techniques of making artefacts is mainly based on Kenoyer and Miller (1999) and Miller (1993).

Casting: By defining casting as the shaping of molten metal they include a wide range of metal working activities, including the production of secondary ingots as well as the casting of semi-finished or finished objects.

Evidence for casting thus includes all of the indicators discussed above under melting, as well as several types of indicators directly related to casting such as moulds, semi-finished objects, and finished objects. Lahiri (1993) also notes the importance of recognising the presence of secondary ingot casting in South Asian metalworking.

The best evidence for casting activities at a site is the presence of moulds. Ancient mould types include open stone, terracotta, or sand moulds; bivalve stone, terracotta, or sand moulds; and terracotta-based "lost model" moulds. Horne (1990) suggests the term "lost model" rather

than "lost wax" since the technique employs other materials besides wax, such as tallow, resin and tar. At present, no convincing examples of any type of mould for casting metal have been reported from Harappan Phase sites.

The only published stone "moulds" from a Harappan Phase site are from Lothal, where Rao identifies two grooved stones as open moulds for casting pins/rods (Rao 1979: 557, 568; Fig. 121, nos. 3 and 4; Pl. CCLIIb). The first problem with Rao's identification is that the grooves are much larger than the metal pins found at Harappan Phase sites. Second, the grooves are not straight along their length or sides and taper off in depth at each end, which seems highly impractical and unlike known casting moulds from other regions and periods. Third, there is no report of discolouring or spalling, which would occur if molten metal were repeatedly poured onto a stone surface. Similar stones (made of sandstone and quartzite) with long parallel grooves have been found at Harappa and Mohenjodaro, and at Chanhudaro they are clearly associated with agate bead manufacturing areas (Mackay 1943: 213-14, Pl. XCIII). Our opinion is that the grooved stones from Lothal probably do not represent open stone moulds for metal casting.

The only published terracotta moulds are also from Lothal, and might be fragments of open moulds, although Rao calls them "crucibles" (Rao 1979: Pl. CCXIIIa, b, c). Scrapings collected from the interiors of these "crucibles" gave negative tests for tin, lead, nickel, arsenic, and copper, even upon repetition of the copper test (Lal 1985: 661). Future test results showing the presence of some metallic traces would be necessary to define these objects as moulds for casting metal (but see Bayley 1989: 298-99). Finally, there are no reports of sand moulds of any kind nor of fragments of lost model moulds.

Paradoxically, the few metallographic analyses that have been done on Harappan Phase copper/bronze objects indicate that some tools were definitely made by open or bivalve casting (Agrawal 1971; Pigott *et al.* 1989; Sana Ullah 1940; Wraight 1940). In addition, the modelled forms of the famous metal figurines of animals and humans can be attributed to lost model casting. For example, two exquisite objects reported from Chanhudaro that may have been made by lost model casting have often been overlooked, a covered cart with the wheels missing, and a complete cart with a driver holding a goad (Mackay 1943: 39, 41, Pl. LVII, 1 and 2). A similar model cart was also recovered in excavations at Harappa (Vats 1940: 27). Some of the small vessels may also have been made by lost wax casting (Mackay 1938: 446; 1943: 176).

Due to the low percentages of lead found in his analyses, Sana Ullah did not think that the Indus peoples used lost model casting techniques (1940). While unalloyed copper is difficult to cast, it should be pointed out that lead is not a prerequisite for lost model casting. Other alloys may be used (*e.g.*, copper-tin), as most alloys are usually fluid enough to cast well. Furthermore, the types of objects tested by Sana Ullah were unlikely to have been made by lost model casting in any case; no figurines or vessels were tested.

Many of the cast Harappan Phase metal objects, particularly the figurines, are definitely Harappan in style, corresponding to the morphology and subject matter of objects in other materials such as faience, stone, and ceramic. There is no evidence for Harappan-style metal objects or moulds from sites outside of the greater Indus region; indeed, Yule (1985b) notes that Harappan Phase metalware is very different in style from contemporaneous products in other regions.

It is more likely that this paradox is due to the lack of identified metal processing areas at the Indus Valley Tradition sites and also perhaps a problem of the archaeological identification of moulds. The Egyptians and Mesopotamians obligingly left moulds of stone, clay, and even metal (Moorey 1985; Scheel 1989); the Indus people were not so helpful. Given the scarcity

of stone in the Indus valley flood plains, it is possible that stone moulds were reused for other purposes. However, this seems extremely unlikely, as the detailed examination of every fragment of stone and fired ceramic recovered from five seasons of excavations at Harappa, as well as examination of the Mohenjodaro reserve collections, have not revealed any fragments of stone or ceramic moulds (Kenoyer, on-going research). Another explanation is that the Indus people used mould materials, such as sand or sandy clays, which leave little trace in the archaeological record. Two techniques using sand or sandy clay moulds are sand casting and lost model casting, both of which leave almost no archaeological traces.

Sand-based moulds are used for casting in modern South Asia and many other areas of the world (Untracht 1975), and employ finely powdered sand, sometimes mixed with water and organics such as dissolved sugars. This mixture can be used to make an open mould or packed into a hinged wooden box to make a bivalve mould. A form made of wood or some other material is impressed into the sand mixture, which is cohesive enough to create a mould into which the molten metal is poured. It is well suited for flat objects, such as celts, axes, adzes, knives or spears. It may even leave characteristic bivalve lines on the objects, often taken to be indicative of the use of stone or terracotta bivalve moulds.

Since forms are used to impress the sand and create the mould, some degree of duplication of objects is possible, and creation of the sand moulds is obviously quite rapid. Although these moulds have a great resistance to heat, making them an excellent casting material, they break down quickly into sandy deposits when exposed to weathering from water and wind. In addition, modern sand moulds are usually ground and reused, and ancient moulds would probably have been similarly recycled.

The materials used to make lost model moulds are also quite ephemeral. These materials form a continuum with the fine sticky sand used for sand casting, but employs more cohesive sandy clay so as to retain better the complex three-dimensional features of the object to be cast.

Lost model casting often employs several grades of material. First, the model of wax, resin, tar, etc., is coated with fine sandy clay. This inner coat will form the details of the object to be cast, so the finer the detail desired, the finer the texture of the coat. Increasingly coarser sandy clay is used to form the bulk of the mould. The crucible containing the metal can be built into the mould, as is done in India and Africa, or metal can be poured into the mould from a separate crucible, as was done in the Americas and Egypt. (See Emmerich 1965; Fox 1988; Fröhlich 1979; Horne 1990; Reeves 1962; Scheel 1989 for ethnographic and historic descriptions of lost model casting.)

An essential component of the lost model process is the use of sandy clay that will not sinter under high temperatures. Thus, in addition to the fact that the moulds are broken to remove the cast object, such moulds also break down very quickly when exposed to weathering. As with sand casting, the broken pieces of the mould are also often recycled, increasing their archaeological invisibility.

The ability to rapidly produce moulds and to recycle the mould materials is one of the great advantages of sand and lost model casting over stone-mould casting. Miller notes that while this is beneficial for the artisan, it is a nightmare for the archaeologist. Perhaps with increasing awareness of these methods and their ephemeral remains, archaeologists will begin to look more closely at patches of sand for the tiny fragments that may still retain the contours of cast objects.

Fabrication: Fabrication of metal objects includes all of the various types of modification of non-molten metal: shaping, via forging, turning and drawing; cutting; cold and hot joining;

and finishing via planishing, filing, polishing, colouring, engraving, and so forth. The metal can be worked while cold or hot, but at a heat below the molten state. Ingots (either secondary or smelting ingots) can be worked either into sheet form or directly into a finished object. Cast semi-finished objects, such as those found by Mackay at Chanhudaro (1943: 175), also would be subsequently worked to form the finished object.

Shaping: In its broad sense, shaping is the controlled mechanical stretching of metal. This includes stretching by forging, including sinking and raising; by spinning or turning; and by drawing.

Forging: The most common form of shaping is forging, "the controlled shaping of metal by the force of a hammer", usually on an anvil or stake (McCreight 1982: 36). Whereas the term "hammering" is sometimes used for non-ferrous metals, and "forging" reserved for ferrous metals, forging is the term most often used by coppersmiths themselves, and will be used here.

The hammer and the anvil or stake can be made of a variety of materials, such as metal, stone, wood, bone or horn, or even leather. Finds of such tools, or of the marks left on objects by such tools, comprise one type of archaeological evidence for forging. The other main source of evidence for forging comes from metallographic examination of artefacts.

Forging can be done while the metal is hot or cold. Forging not only shapes the object, it also hardens it, and so forging is an important step in the manufacture of edged tools. Annealing is the re-heating of an object after working, and most metalworking involves cycles of annealing and hot or cold "hammering" (forging). Metallographic studies help to establish the use of such methods.

There is some evidence for forging during the Harappan Phase, both from finds of tool marks and from metallography (Agrawal 1971; Mackay 1938; Pigott *et al.* 1989; Sana Ullah 1940; Wraight 1940). The Indus peoples forged objects both from castings, including bar or block ingots and semi-finished shapes, and from sheet metal. For example, chisels, which are one of the most numerous tool types, appear to have been forged from cast bars (*e.g.*, Vats 1940: 87-88). Metallographic analyses of other edged tools confirm that at least some of these tools were cast and then forged (Agrawal 1971; Pigott *et al.* 1989; Sana Ullah 1940; Wraight 1940). Thin razors are thought to have been cut from copper sheets, then forged to a sharp edge (Mackay 1938, 1943).

Sheet manufacture is a type of forging, and fragments of copper, silver, and/or gold sheets have been found at Chanhudaro (Mackay 1943), Harappa (Vats 1940), Lothal (Rao 1979, 1985), and Mohenjodaro (Mackay 1931, 1938; Marshall 1931). The Indus method of sheet manufacture is unknown, and there are no published anvils or hammers. However, many of the non-cubical "weights" from Harappan Phase sites are very smooth cylindrical or semi-hemispherical stones with highly polished surfaces. These types of objects might well have been used for metalworking, and the highly polished surface would be necessary to avoid marring the metal. The reports of hematite and magnetite "hammerstones" from Afghanistan (Dupree 1963; Shaffer 1984) are particularly interesting, given the use of these materials in copper metal sheet manufacture in western Iran (Pigott, *in press*).

Use-wear studies of these stone objects may help to clarify their function. It is also possible that wood or other perishable materials were used. At this time, the most hopeful method for elucidating the methods and materials used by the Indus peoples for forging is through the analysis of objects for tool marks, particularly on the better-preserved gold objects. Experimental studies aimed at discriminating marks left by various tool materials (*e.g.* stone, wood, metal) will also

be useful.

Sinking and raising to form vessels from metal are also types of forging. As the names imply, sinking is the forming of metal by hammering from the interior of an object into a depression in an anvil, while raising employs hammering from the exterior of the object over a shaped stake or form. There are a number of ways to raise objects: both from sheets and directly from ingots, while the metal is cold and while it is hot, by an individual artisan or by a group working together. The Indus people are known to have raised vessels (Mackay 1938: chap. XIII; Vats 1940), and appear to have made some jewellery by similar forming techniques, particularly the gold "cones". Unfortunately, no studies have been done to show what techniques of raising or sinking were employed.

Hollow metal tubes of copper or copper alloys were also made. The method of production is not exactly known, but the tubes are seamed and were produced from sheets, and so were forged in some fashion (Mackay 1943). The edges do not overlap, but rather abut, and there is no mention of the use of solder in the published accounts. The handled pans (Mackay 1931, 1938, 1943) also show the production of tubes by raising, in that their handles are tubes made by lapping over the opposite sides of the metal. Two pieces of a long, 2.5 cm diameter copper tube were also found at Mohenjodaro, but no details of its construction are given. Marshall refers to this tube as a "coppersmith's blow pipe", but gives absolutely no support for such a conjecture (Marshall 1931: 198).

Decorative uses of forging include the use of stamps or punches, hammering of thin metal sheet (often gold) into or over patterns, and chasing. Hammering into or over patterns is not noted so far, but simple circular punch marks were used in the decoration of gold objects and fillets (*e.g.*, Mackay 1938: 526, no. 4; Marshall 1931: 527, Pl. CXVIII, 14), and sheet metal was beaten out from one side to make designs in at least one piece (Vats 1940: 64, [d] no. 8). There are no published reports of true chasing (the working of metal from both sides).

Spinning and turning: Spinning and turning are methods of mechanical stretching with results similar to sinking and raising but using a lathe rather than a hammer. While Mackay originally suggested that some of the vessels from Mohenjodaro may have been made by turning (1931), no lathe marks or evidence for a lathe have yet been discovered to support this conjecture, and Mackay seems to discard it in later writings.

Drawing: Wire production has not been studied at all, although there are abundant examples of copper "wire" and silver "wire". This is probably due to the poor preservation of the metal, so that details of manufacture are not discernible. There is no evidence at present to indicate whether Harappan Phase wire was drawn or forged, although the latter is far more likely for the third millennium BC. Wire was used to make rings, possibly for adorning the fingers, toes and ears, as well as for other purposes. Some stone beads have pieces of copper wire inserted through the hole, possibly in imitation of the method seen with gold wire so that the bead could be hung as a pendant from a larger composite necklace.

When corroded wire remains inside a bead, it will often split the bead into two fragments, making the bead look as if it was broken in manufacture. Occasional reports of copper "drill bits" found stuck in beads may be such fragments of corroded wire. For example, Jarrige mentions that a long barrel-shaped lapis lazuli bead from Mehrgarh, Period VII with a "copper bit" still inserted in the hole, was broken in two during the drilling process (Jarrige 1985b). This may instead be a fragment of the copper wire used for stringing the bead. However, further investigation of these reports is needed, as the possible use of copper for drill bits is an important unanswered

question for the Indus Valley Tradition (Kenoyer and Vidale 1992). Jarrige's discussion (1985a: 290) of the helicoidal bronze rods from Lothal, Mundigak, and perhaps Mehrgarh is of great interest for this topic. These rods are exactly like modern auger drills, and the rods from Lothal and Mundigak still retain their pointed tip. Jarrige (1985a: 290) also notes that the helicoidal rod from Mundigak corresponds in diameter to the hafting holes in wooden handles found at Shahr-i-Sokhta.

Cutting: The Indus peoples are thought to have cut many of their thin objects out of sheet metal. Cutting was probably done for the most part with chisels (Mackay 1938: chap. XIII, and many other cases); the V-shaped or double-edged chisels, which are the most common type, can be used to cut metal. Most of the chisels analysed to date are of tin bronze or arsenical copper, and therefore relatively hard. In addition, there are some saw marks in metal objects (Mackay 1938: 368, 452, 475, 583), although Mackay was unable to distinguish if these were from an ordinary blade saw or a wire saw. From the evidence of both chisel and saw marks, the usual procedure seems to have been to cut a groove in the metal mass on one or more sides, then snap the piece in two. Similar methods are seen in Indus Valley Tradition stone working.

Joining: The number of identified Harappan Phase methods of joining metal is limited. There are very few examples of cold joining, comprising primarily the use of rivets to attach metal handles to metal vessels (Marshall 1931).

Hot joining is represented by evidence for soldering of gold and silver (Sana Ullah 1940; Rao 1979), and by one example of pouring molten copper metal over a join to attach a copper handle securely to a copper vessel (Mackay 1931: 489). (Hot joining is considered a fabrication technique even though the joining material is molten, because the body of the metal is not molten.) There are as yet no published examples of soldering of copper materials, but this is probably due to the generally poor state of preservation of the copper metal and the lack of analysis. For example, a large cooking vessel found at Chanhudaro appears to have been joined at the carination. However, it is not yet clear if this joint was cold or hot joined, due to the poor preservation of the object (Kenoyer, on-going research at the Museum of Fine Arts, Boston).

One possible example of hot joining without solder is seen in a gold tubular bead from Harappa, measuring 33.95 mm in length and between 2.14 and 2.41 mm in diameter. The thickness of the gold wall of the tube is between 0.34 and 0.39 mm and there is no visible longitudinal seam. Further studies of the bead are needed to confirm the precise techniques, but one possible method of manufacture was reproduced in silver by a skilled jeweller in Karachi (Kenoyer, on-going research). A long silver wire was wrapped around a solid rod, and the wire was fused into a tube by vigorous burnishing and annealing. If this were the manufacturing method of the ancient tubular bead, casts of the interior of the gold tube should reveal whorls along the circumference.

Another find from Harappa perhaps related to joining is the discovery of a tiny snippet of gold that is a swollen pillow shape (4.35-mm length, 1.39-mm width, 1.58-mm thickness). This type of object is often seen in the process of manufacturing granules of gold for use in granulated decoration. However, such granules are also a standard by-product of soldering, for the intentional or unintentional heating of a tiny gold, silver, or copper fragment often results in such a shape. The essential step defining granulation is not the making of the granules, but the attachment of the granules. At present no ornaments with gold granulation have been found from Indus Valley Tradition sites.

Finishing: There have been few discussions of Harappan Phase metal finishing techniques

(Mackay 1938). While this is understandable for the copper-based objects, which are generally heavily corroded, the silver and especially the gold objects should provide evidence for Indus methods of finishing.

Finishing techniques which need to be investigated include the planishing of forged (especially raised) objects; filing and polishing to smooth surfaces; engraving; inlay and stone-setting; and surface coloration via plating or enrichment.

Mackay notes the presence of hammer marks on many of the vessels, but does not indicate if this represents planishing. (Planishing refers to fine, even hammering with a highly polished hammer, used particularly to create a smoother surface on forged objects.) Evidence for polishing comes from the gold objects from recent excavations at Harappa, such as the copper and gold beads, which show minute striae oriented in groups.

Polishing materials could have included ground and polished stone objects, perhaps even magnetite nodules, sand or silt-sized powders, plants, or even leather. Engraving to produce designs or accentuate details is known from the figurines and the numerous inscriptions on copper tablets and other metal objects (Yule 1985a, 1985b). Stone burins or metal engravers may have been used for this technique, and could probably be identified through use-wear studies. Finally, a number of inlaid pieces are found amongst the Indus jewellery, although the techniques of setting have not yet been studied.

At present there is no evidence for surface coloration via plating or chemical enrichment. However, the mechanical wrapping of gold sheet over copper and paste beads is known from Mohenjodaro (Mackay 1938) and Harappa (Dales and Kenoyer 1990), as well as from Allahdino (Fairervis: personal communication). At Harappa, the gold sheet used for wrapping the core ranges in thickness from 0.07 to 0.1 mm in thickness; it appears to only have been wrapped and hammered around the core without having been actually fused to it.

Miller pleads that more precise information on finishing, and manufacturing techniques in general, would benefit greatly from the re-study of all objects in a standardised fashion, using xeroradiography of the objects and selected metallography. Methods of manufacture would give us more information on the diffusion and independent invention of metal processing techniques in the Indus Valley Tradition. It would also allow investigation of possible regional styles of production both within the Indus Valley Tradition (*e.g.*, Indus Valley vs. Gujarat sites), and in contrast with other Traditions (*e.g.*, Indus Valley vs. the Rajasthani cultures, or even Mesopotamian groups).

TECHNOLOGY OF THE CHALCOLITHIC CULTURES

The term "Chalcolithic cultures" in India is used to include non-urban, non-Harappan cultures characterised by the use of copper and stone. These cultures make their first appearance at the turn of the second millennium BC and are eventually replaced by the iron-using cultures. Unlike the Harappa culture, these cultures show a distinct regional identity probably determined by smaller ecological units. Southeastern Rajasthan gives rise to the Banas culture, the Malwa region to the Kayatha culture and the mid-Ganga Valley to the Ochre Coloured Pottery (OCP) culture. The main differences among these cultures lie in their characteristic ceramics, though economically they at a similar stage. A limited amount of copper and an abundance of lithic blades mark most of these cultures. (For more details of these cultures see chapter 7).

The **Banas Culture** is named after the river Banas on whose banks the Banasian sites were found. Though more than fifty sites of the culture are known in the valleys of Rives and Berach

in Southeast Rajasthan, excavations were conducted only at Ahar, Gilund and Kayatha and Balathal. At Ahar only copper was used and no stone blades. At Ahar five axes, one knife blade, one sheet, a bangle and two rings of copper have been reported. The copper technology however seems to be poor, compared to the Harappans: the axes have blowholes and there is no evidence of work hardening.

Kayatha, situated on the bank of the Kalisindh, an affluent of the Chambal gives the Kayatha culture its name. The Kayathans show a relative abundance of copper as from one pot alone, twenty-eight copper objects were recovered. The two copper axes with a sharp cutting edge and a lenticular section are the finest examples in the Bronze Age India. The axes are cast in a mould unlike the later Chalcolithic specimens which were just hammered to shape in central India and the Deccan. A chisel is also reported from here.

Malwa, in western Madhya Pradesh, is the main seat of the Malwa and the Kayatha cultures. The Malwa culture is marked by the Malwa ware, use of copper and stone tools, and small settlements of wattle and daub huts. Flat copper celts with convex cutting edges, arrow-heads, spearhead and chisels form an important part of the tool repertoire. Except for the mid-ribbed sword which must have been cast, other objects appear to have been hammered to shape. Artefacts like blades, bangles and rings were also made of copper. Cold work and annealing were known to these people. A comparison of the impurity patterns of ores and these artefacts has been carried out to locate the copper mines used. Tin was alloyed up to 3% and lead to about 2%; no arsenical coppers are known, except the ones reported by Rapp (1986).

Earlier we had compared the alloying patterns among the Harappan, Chalcolithic and Copper Hoard technologies and found that arsenic alloying is confined to the Copper Hoards and the Harappans (Fig. 3.1). There was no tin alloying in the Copper Hoards at all. We had therefore inferred that there was no technological interaction among these cultures. However, Rapp has reported some Chalcolithic artefacts with arsenic.

The Jorwe culture covers most of the Deccan plateau. The Jorwe ware is the hallmark of this culture. Copper was used to make axes, chisels, knives, fish-hooks, beads and bangles. A boat-shaped kiln to smelt copper ores has been identified at Inamgaon. Very few artefacts have been chemically analysed. An axe from Jorwe and a chisel from Nevasa show 1.8–2.8% tin alloying.

Shinde (1991: 806) writes, "A large number of copper objects have been recovered from the excavations of Inamgaon and Daimabad. The discovery of a copper smelting furnace and a lump of copper ore at Inamgaon suggests that copper ore was smelted at the site and the objects were fashioned locally. The copper must have been extracted from the chalcopyrites, which occur locally. A boat-shaped furnace built of clay on a stone foundation was encountered close to the pottery kiln at Inamgaon. An oval-shaped clay cushion similar to that from the pottery kiln but without a central hole was found in the centre of the furnace, possibly to support ore...". He further reports two U-shaped furnaces from house no. 9 from Daimabad, along with a heart-shaped copper razor (see Fig. 7.11).

In the eastern zone are included the present states of Bihar, Bengal and Orissa. The excavated sites, however, are largely confined to Bihar and Bengal. Chirand is located on the confluence of the Ganga and the Ghagra in district Saran, Bihar. Recent excavations have pushed back Chirand's antiquity into the II millennium BC. Period I at the site is Neolithic, free of metal; Period II is Chalcolithic; and Period III is marked by the appearance of iron. Copper artefacts are few and include tanged arrow-heads, a ring, bangles, antimony rod etc. No other details are known about the copper technology.

Rapp (1986) reports (see Table 2.1) thirteen new analyses from the Chalcolithic cultures of India. As can readily be seen, ten of the samples are unalloyed copper (less than 1% of any alloying element), whereas the remaining three (numbers 1, 6, and 10) are arsenic bronzes with 2.06%, 2.40%, and 4.84% arsenic, respectively. This is the first time that arsenic has been reported in the Chalcolithic artefacts.

Rapp claims that careful investigations of the chemistry of artefacts and related ores frequently can lead to distinguishing smelted copper from native copper. (For ore-artefact correlations see chapter 2.)

After completing our discussions on mines, mining and metal using techniques, we will now take up the metal technologies of different protohistoric cultures. In the next chapter we begin with the Pre-Harappan cultures which set the stage for the Harappan urbanisation.

(NOTE: Much of the material on the Harappan technology will be published in Kenoyer & Miller 1999, although this chapter represents an update of the material. The references mentioned in their excerpts are not always included in my bibliography. I am grateful to these authors for allowing me to use their unpublished material here – D.P. Agrawal).

CHAPTER 4

PRE-HARAPPAN METALLURGY : PRELUDE TO
HARAPPAN URBANISATION

CONTENTS

- INTRODUCTION
- PRE-HARAPPAN CULTURES

INTRODUCTION

There was a time when it was thought that the Harappa culture came on the scene out of the blue and therefore had to be a direct implant from West Asia, or at least the product of an "idea diffusion". But recent work in the Northwest of the subcontinent has clearly established the indigenous development of urban cultures from hunting-gathering and the Neolithic stages. Below, we trace this evolution in the Northwest of the subcontinent in some detail to understand the development of crafts and metal technology.

Kenoyer and Miller (1999) reflect the same concern in dealing with the problem of Harappan archaeometallurgy. They say, "The extensive overlapping exchange networks that connected the greater Indus region to the metal resource areas of West Asia, eastern Iran and Rajasthan make it difficult to determine the role of diffusion in the origins and dispersal of various metal technologies, especially copper metallurgy. The simplistic yet pervasive model that copper working technology was developed somewhere in West Asia and diffused to adjacent regions such as the greater Indus region is based on assumptions regarding human cultural interaction and the control of knowledge that are not supported by the archaeological data currently available for study (Kenoyer 1989). Throughout West and South Asia, beginning in the Palaeolithic and continuing through the Neolithic we find evidence for a familiarity with fire and its effect on various materials. In the Upper Palaeolithic, iron ores were routinely roasted to make pigments (Schmandt-Besserat 1980) and chert was heated to make it more flakable. During the Neolithic and early Chalcolithic, pyrotechnologies included the firing of different types of clays to make ceramics, and the heating of lithic materials to enhance colour, workability, and/or hardness. Although we have no direct evidence for the earliest metal procurement techniques, it is not unlikely that fire setting was being used to extract native copper lumps and granules that could then be further processed by hammering and annealing. The many different pyrotechnologies in practice make it unreasonable to assume that the discovery of metal smelting and melting was simply an accident, and not the result of intentional experimentation and innovation".

"For the greater Indus region, the evidence from Mehrgarh and other early sites demonstrates

that the pyrotechnological and metallurgical innovations of the Neolithic and Chalcolithic set the technological background for the metallurgical traditions of the Harappan Phase (Jarrige 1985b; Jarrige and Lechevallier 1979). It is clear that the origin and development of copper metal technology occurred in conjunction with developments in other technologies. At the site of Mehrgarh during the 5th to 4th millennium BC, changes were occurring simultaneously in metal production, ceramic production, the drilling of hard stone, production of fired and glazed steatite beads, and shell working. A decrease in the use of certain types of bone and stone tools is also seen at this time (Jarrige 1983). The transitions seen at Mehrgarh between the Neolithic and the Chalcolithic have numerous parallels with similar changes in the highlands of Baluchistan and other regions of the greater Indus region. Sites such as Nausharo (Jarrige 1990), Balakot (Dales 1979), Ghazi Shah (Flam 1993), Rehman Dheri (Durrani 1988) and Kalibangan (Agrawala 1984a; Lal and Thapar 1967) all show evidence for the use of copper in the period prior to the Harappan Phase, along with changes in other technologies.

"Throughout southern and northern Baluchistan, Afghanistan and Rajasthan, the combined resources of metal ores and fuel were available to communities of sedentary agriculturists and semi-nomadic pastoralists. Such communities were undoubtedly familiar with the properties of ores and how to extract the metal long before it became an important economic process. Furthermore, it is highly unlikely that the process for smelting ores and processing copper was discovered only in one isolated area, since there is increasing evidence that the highland communities of West and South Asia were connected by numerous overlapping networks, both economic and social (Kenoyer 1991).

"Since there are many regions of West Asia and South Asia that are rich in both metal ores and fuel, it is quite likely that regional styles of pyrotechnologies evolved according to the physical characteristics of locally available ores. Over time, in adjacent regions such as northern and southern Baluchistan, the regional styles that were less effective and/or practised by socio-politically weaker communities would have been eliminated or absorbed through competition. More widely separated regions such as Baluchistan and Rajasthan, which are divided by the Indus valley flood plains, may have retained their styles and continued to function parallel to each other for a longer period of time. Future studies of regional styles of metal processing and use may provide valuable information for understanding the development of a possible Indus technological style or multiple technological styles" (see Lechtman and Steinberg 1979).

Jarrige (1993:83), whose excavations in the North-west have thrown new light on the origins of Mature Harappa Culture, emphasises that the culture traditions of the third and fourth millennia in Baluchistan and the Indus valley are deeply rooted in local traditions beginning with a very early Neolithic.

It is worth noting here Bhan *et al.* (1994: 150) views, "The Harappans had a well developed and highly specialised metal technology, but oddly enough it is one of the least studied craft traditions". Although we have numerous metal objects, ranging from gold and silver to copper and bronze, few of these objects have been subjected to metallurgical or compositional analysis (Agrawal 1971, 1984; Pigott *et al.* 1989; see Kenoyer and Miller 1995 for a comprehensive summary). Furthermore, metal processing workshops have not been well documented in the major cities or in the rural settlements, and no excavations have been undertaken at remote sites near the resource areas, where metal processing should be found.

Given the fumes, smoke, and fire associated with metal processing, these workshops may not have been situated on the high, mounded positions of the settlements and may be buried

beneath the alluvium or at the edges of the sites. On the other hand, it is also possible that the infrastructure of Harappan craft production, such as the site of Chanhudaro, which seems to be a specialised lapidary production site and Nageshwar, a shell working site on the Gulf of Kachchh may also have helped. The currently unexcavated sites of Cholistan and the Pakistan-Indian border may supply evidence for a great deal of metal working, as hinted at by large-scale surface surveys (Mughal 1982; Agrawala 1984) (Bhan *et al.* 1994:150).

Most of the analyzed metal objects come from the major urban centers and date to the Harappan Phase, between 2600 and 1900 BC. Copper or copper alloys dominate the metal assemblage, and can be divided into four categories: (1) crude copper (derived from smelting and rich in sulphur), (2) refined copper, (3) arsenical bronze and (4) tin bronze (Sana Ullah 1931). No objects of native copper have been identified as yet, but they will undoubtedly be found in the future. Other processed metals include lead, gold, silver and electrum, but no confirmed iron objects or brass objects have been reported from Harappan Phase sites in the greater Indus region.

As noted in chapter 2, Kenoyer and Miller inform that "Actual copper minerals (*e.g.* chrysocolla, chalcopyrite, malachite, etc.) are rare at Harappa Phase sites in the core areas of the greater Indus valley as are other metal minerals such as haematite, lollingite (arsenic and iron), antimony, cinnabar (sulphide of mercury), cerussite (carbonate of lead), galena, and an unidentified type of lead ore recently recovered from excavations at Harappa. Although some of these metallic ores may have been used in copper melting and alloying processes, such as for colorants, cosmetics, medicines or even poisons. Given the low occurrence of raw materials, it is assumed that most of the initial stages of smelting and preparing ingots was undertaken in remote resource areas near the metal ore and forests that would have been necessary for the preparation of charcoal. Major regions for copper ores are northern and southern Baluchistan, the northern Aravalli range and more distant Oman" (Kenoyer and Miller in press). It is not unlikely that all of these sources were exploited by the Harappans, stimulating an important market dynamic because of the different types of metals available from each region and the different distances involved.

Lal (1997) reflects the same view, "It is now abundantly clear that one need not look any longer to West Asia for finding the 'roots' of or even inspiration for this great civilization of South Asia. This region itself has given ample proof of its infancy, adolescence and maturity". Lal (1997) has also provided an excellent summary of the pre-Harappan cultures.

To trace the urbanisation processes in the Northwest South Asia, and also the evolution of metallurgy, let us now survey some important pre-Mature Harappan sites and their metal inventories wherever available. The following survey is mainly based on original excavation reports, Lal (1997) and Kenoyer's new book, *Indus Valley Civilisation* (1998). The Harappan phase of the sites will be discussed in chapter 5.

PRE-HARAPPAN CULTURES

Aq Kupruk

In Afghanistan, at Aq Kupruk (Dupree 1972; Shaffer 1978) the remains of an epipalaeolithic (last stage of Palaeolithic cultures) culture go back to c. 15,000 BC, followed by a Neolithic culture with the evidence of domestication of sheep and goat. These Neolithic levels, without pottery, have provided two uncorrected (5730- half-life based) radiocarbon dates, viz. 8565 ± 240 BC and 6960 ± 105 BC (approximately 10,000-8,000 BC calibrated). The subsequent ceramic-

bearing levels are dated by four dates viz. 5806 BC, 5638 BC, 5292/5286/5241 BC and 3307-3110 BC (Possehl 1990:3-4). Thus, the beginning of the ceramic Neolithic, hence of pyrotechnology, in South Asia goes back to the sixth millennium BC.

Kile Ghul Mohammed

Lal's (1997: 32-91) recent survey of the pre-Harappan scene of the subcontinent gives a fair idea of the antecedent cultures that preceded the urban phase of the Harappa culture. Walter A. Fairservis had unearthed evidence of pre-pottery Neolithic culture at Kile Ghul Mohammad (or KGM or Kili Ghul Mohammed), near Quetta, in Baluchistan (Fairservis 1956). Period I yielded evidence of microliths, structural remains of wattle-and-daub and domestication of the cattle, sheep and goat. There are three radiocarbon calibrated dates, viz. 4352 BC, 4346 BC and 4210 BC (Possehl 1990: 29) from Period I. Period II has also a handmade crude ware, sometimes bearing basket-impressions. Metal and wheel turned pottery with painted motifs appear only in Period II.

Mundigak

Shaffer (1978) reports that metal artefacts were first found in Period I, and increase in frequency and variety throughout the sequence. The earliest example was a flat blade like instrument which might have had a hafting tang. However, the most frequent metal artefact of the entire Mundigak sequence was a simple type of bronze point or punch with a circular cross-section. It was first identified in Period I and is so easily available that it replaces the bone awl/punch in Period IV. A single example of this point/punch was found in Period III. A tanged lozenge-shaped point was introduced in Period IV. The first examples of "luxury" type metal artefacts were located in Period II. These two artefacts were pins, one with a double-volute while the other had a flattened and perforated end. Similar pins with flat ends and twisted shafts were also found in Period III. However, the greatest number of the variety of "luxury" type objects was found in Period IV. Among such objects identified were: concave discs (mirrors); double-volute, lozenge, and broad-flat headed pins; handles for discs (mirrors); and a buckle. It is important to note that in at least two instances smelted (?) *iron* decorative buttons were found on objects in Period IV. Frequently encountered utilitarian objects in Periods III-IV were small curved knives or sickles and chisels, and only in Period IV, a few barbed hooks. Three important metal artefacts located in Period III were the only examples of socket-hole axes (two) and an adze. Most of the more common utilitarian and "luxury" metal artefacts were also identified in Period V.

Elemental analysis of some of these artefacts indicated some interesting aspects of the metallurgical sophistication represented by these objects. Analysis of one artefact from Period I demonstrated that it was a very low-tin bronze. Tin accounted for only about 1%, iron 0.15% and the remaining material was copper. Such a composition is a striking contrast to the high tin content of the chronologically earlier material located at Ghar-i-Mar. Of the artefacts subjected to analysis from Period II only the axes and adze had a composition approaching that usually associated with bronze. These artefacts had a tin content of almost 5%; the highest recorded at Mundigak. This contrasts with composition of other artefacts from this period which is similar to that of Period I. Axes and adzes rely on weight, force and hardness for their efficiency as a tool. Such characteristics are maximised by a high tin content. Other artefacts such as points, pins or knives have different usage requiring different characteristics and this is reflected in their lower tin content. Therefore, by Period II the differential characteristics of various alloying compositions had been recognised and metallurgy was entering, or had entered, into a new phase

of sophistication and presumably specialisation. During Period IV the tin content of such items as pins increase slightly (1.5%) and traces of lead (1.6%) and other elements are found (Shaffer 1978).

Said Qala Tepe

Said Qala Tepe is located approximately 90 km southeast of Mundigak near Kandahar city. This site is not comparable to Mundigak in terms of its absolute size (8 m of elevation and 200 m in diameter), area of excavations (two 10 m squares and a 6 x 2 m sondage), or extensiveness of the cultural sequence (all occupations correspond to Mundigak III-IV) (Shaffer 1978) but the excavation at Said Qala utilized more careful methods of artefacts retrieval and emphasised quantitative analysis of those artefacts to a much greater degree than the Mundigak excavations. The site was first tested by Fairservis (1952). However, the major excavation differs from previous reports on these excavations, principally in that previous reports retained the field designations for major occupations which were numbered from top to bottom, whereas here major occupations will be numbered from the bottom to reflect the site sequence.

Shaffer (1978) reports from Said Qala Tepe that the MASCA corrected dates are: Period I = 2110 BC; and Period III = 2230 BC. It is important to note that all the dates are basically contemporary, i.e. end of the third millennium BC. Such contemporaneity corresponds with the type of cultural material recovered which indicates that all occupations at Said Qala are essentially equatable with those of Mundigak Periods III – IV.

Bronze artefacts are confined to the latest prehistoric occupation (end of Period II-IV) and were located predominantly in the habitation areas. Identifiable functional artefacts included sickles, blade fragments (?), a lanceolate or lozenge tanged point, and a point or punch with circular cross-section. "Luxury" items in the form of pins were found in Periods II-IV. Although most examples were fragmentary, the following styles could be identified: double volute head, flattened with forked end and simple forked end with twisted haft. A single example of a bronze handle(?) fragments with rounded and perforated distal end was found. In general the artefacts are very similar to those found in Mundigak III (Shaffer 1978).

Mehrgarh

Between Mehrgarh and Nausharo, one can trace the total urbanisation process in the Northwest, hence it may be useful to go into some details of these two crucial sites.

Mehrgarh and Nausharo, about 100 km from Kile-Ghul-Mohammed (KGM), in the Bolan river valley in the Kachhi plains, provide a continuous evolution from the pre-pottery Neolithic stage (seventh millennium BC) right up to the second millennium BC (Jarrige 1981, 1982, 1984, 1986, 1988, 1989; Jarrige and Lechevallier 1979).

The lowest levels of Mehrgarh, in area MR-3, yield a Neolithic culture with stone and bone tools: polished axes, adzes and chisels, as also parallel-sided retouched blades, borers, scrapers, triangles, trapezes, lunates and microborers. It is only in the later part (Period IB) that a coarse ware with basket-impressions made its appearance. The economy was based on hunting and herding animals and cultivating cereals. While the lower levels yield bones of wild animals, in the upper levels the faunal remains were mostly of domesticated animals, including sheep, goat and cattle. The cereals include: einkorn wheat (*Triticum monococcum*), emmer wheat (*T. dicoccum*), and bread wheat (*T. durum/aestivum*); and two-row hulled barely (*Hordeum distichum*) and six-row barley

(*H.vulgare* and *H.vulgare* var. *nudum*).

The houses were made of mud bricks of sizes viz., 28 x 14.5 x 7 cm and 33 x 14.5 x 7 cm. The former yields a ratio of 4:2:1 which is the ratio of the bricks used in the Harappan times and thus shows the continuity of the concept. The houses were multi-roomed, with interconnecting doors.

In the burials, the body was placed in a pit either in an extended position or flexed, lying on the right side. The excavators state (Jarrige 1982:82) that "in one case the traces of a red ochre-coloured textiles were visible on the bones". The accompanying grave-goods were pretty rich and included necklaces of micro-beads of steatite interspersed with those of turquoise and lapis lazuli. There were ornaments of seashell as well. The presence of a bead of copper in one of the burials is also worth noting. There were tools of stone and a variety of microliths. Likewise, there were baskets coated with bitumen to make them impervious. In two rich burials, five young goats were also interred.

It is obvious that the bead manufacture technology of very tiny beads of steatite, and of turquoise and lapis lazuli, and ornaments of seashell have economic and organisational implications. None of the aforesaid three materials is available in the neighbourhood of Mehrgarh. While lapis lazuli is likely to have come from Afghanistan, turquoise may have been obtained from Iran or Central Asia, although the possibility of some sources in Baluchistan is also there. The seashells too must have been brought from a distance of at least 500 km from the Arabian Sea. All this would mean long-distance trade, which implies a fairly good organisational set-up.

For the Neolithic culture at Mehrgarh, eighteen radiocarbon dates (Table 4.1) are available: eight for Subperiod IA and ten for Subperiod IB (Possehl 1990: 35-36). The earliest dates for Subperiod IA are 5980 BC and 5749 BC. The beginning of the Neolithic occupation at Mehrgarh may be placed around 6000 BC, but it may well go back into the seventh millennium BC. With a total occupational deposit of 10 m, the end of Period I may be placed around 4500 BC. Period II as a whole may be placed in the second half of the fifth millennium BC.

Only by Subperiod IIB pottery came to be better fired and the clay used was also better levigated. In Subperiod IIC the wheel-made painted pottery appears. The use of axes and adzes began to decrease, while large blades dominated the microlithic assemblage. Important are two sickles, each consisting of three bladelets set in wood with bitumen. Copper is represented only by a ring and a bead, suggesting that metal was still scarce. Two terracotta human figurines and bangles with triangular cross-section are other important finds.

Cultivation of barley (*Hordeum sphaerococcum*) shows the beginnings of irrigation as it can grow only in irrigated fields. Seeds of cotton and a granary structure were also found, thus heralding proper copper technology.

Period III may be placed in the first half of the fourth millennium BC. In Period III the size of the settlement had grown considerably. During this period there was an explosion in the painted designs. The most conspicuous was the depiction of birds and animals in a row. Period III is also to be noted for the earliest occurrence of oats (*Avena sp.*) and for the addition of one more variety of wheat, viz. *Triticum sphaerococcum*.

In Period III, fragments of crucibles with traces of melted copper, and bun-shaped copper ingots were also found.

Roughly square and oriented approximately along the cardinal directions, there are planned structures. Small sizes of the cells and absence of doors indicate that these were precursors of the granaries at Harappa and Mohenjodaro. If these indeed were granaries, they may indicate

some central authority.

Table 4.1 ^{14}C Dates from Mehargarh

Subperiod	Lab No.	Half-Life 5730	Calib-2
I B	LV-910	4105 $\pm$ 105 BC	4782 BC
I B	LV-909	4170 $\pm$ 5 BC	4892, 4887, 4841 BC
I B	LV-906	4180 $\pm$ 65 BC	4894, 4883, 4845 BC
I B	LV-907	4250 $\pm$ 80 BC	4937, 4917, 4907 BC
I B	LV-908	4325 $\pm$ 70 BC	5046, 5019, 5004 BC
I B	LV-993	4345 $\pm$ 95 BC	5190, 5058 BC
I B	LV-994	4530 $\pm$ 70 BC	5238 BC
I B	LY-1950	6745 $\pm$ 260 BC	None
I B	BETA-1719	11,790 $\pm$ 130 BC	None
I B	LY-1946	31,680 $\pm$ 3090, -2265 BC	None
I B	LY-1949	3745 $\pm$ 185 BC	4360 BC
I B	LY-1948	3940 $\pm$ 750 BC	4653, 4648, 4581 BC
I B	LY-1947	4055 $\pm$ 195 BC	4725 BC
I B	BETA-2686	4085 $\pm$ 70 BC	4777 BC
I B	BETA-7316	4220 $\pm$ 125 BC	4931, 4928, 4901 BC
I B	BETA-1408	5185 $\pm$ 80 BC	5749 BC
I B	BETA-1407	5380 $\pm$ 300 BC	5980 BC
I B	BETA-1721	7715 $\pm$ 125 BC	None

By Period IV, the occupation extended further southward, towards MR-I. It is marked by the emergence of polychrome pottery. The noteworthy finds of this period are armless terracotta female figurines with somewhat cylindrical head, pinched nose and pendulous breasts, seated with outstretched joint legs, stamped seals of terracotta and bone. There are two radiocarbon dates for this period, viz. 2800 and 1997 BC.

There was a short-lived Period V, marked by a decrease in polychromy. Period VI (radiocarbon date, 2470 BC) shows an explosion in pottery styles and a proliferation of terracotta figurines. Amongst the motifs are the pipal-leaf and humped bull with large dot-centred eyes and long horns in the Kulli style. Large circular pottery kilns indicate an advance in pyrotechnology. Period VI seems to mark the advent of urbanisation.

A chisel, a flat axe and a double-spiral-headed pin were the copper artefacts, as also compartmented seals, both in terracotta and stone.

Jarrige has assigned Period VII to mid-third millennium BC. Some of the pottery forms have resemblance with the Harappan repertoire. The typically Harappan designs of pipal-leaf, fish-scale and intersecting circles had begun to appear in Period VII. The terracotta humped bull reminds one of the Harappan counterparts. The designs on terracotta seals include the swastika, cruciform motifs and what looks like running animals.

The main find of this period is a very large mud-brick platform. Close to it there was a long wall with a series of square pilasters. Whatever may have been the precise use to which this platform was put, it does show a move towards monumentality in architecture — a feature

indicating urbanisation.

Within the habitation area was found a burial inside a clay box measuring 1.10 x 0.80 m of a flexed skeleton on its right side with the head towards the east. The person wore a necklace of kaolin, carnelian and lapis lazuli beads and wristlets of tiny white beads.

Period VIII, contemporary with the late Harappan, at the site is represented by some structures and graves associated with a red ceramic industry and beads of semi-precious stone.

Bronze objects including a shaft-hole axe mark the first occurrence of the type at this site. Jarrige (1993:83) emphasises that "the discoveries made at Mehrgarh in the deposits of the fifth and sixth millennia have a deep significance. They reveal the great antiquity of a farming economy, of craft specialisation and of long distance contacts (turquoise, lapis lazuli and seashell) in Baluchistan. Further excavation in the deepest Neolithic deposits, so far unexplored, will throw new light on the part played by the north-western region of the Indo-Pakistan subcontinent in the cultural processes which led to the development of the earliest farming communities. The culture traditions of the third and fourth millennia in Baluchistan and the Indus valley are deeply rooted in local traditions beginning with a very early Neolithic".

Nausharo

The site is located about 6 km south of Mehrgarh. Excavations at Nausharo have revealed that the site was occupied for the first time around the end of the Period VI of Mehrgarh, i.e. somewhere in the first quarter of the third millennium BC. The earliest occupation at Nausharo has been designated as Period I. A closer examination of its cultural equipment has led the excavator to divide it into four subperiods, viz. IA, IB, IC and ID. Of these, the former three can be equated with subperiods VIIA, VIIB, VIIC of Mehrgarh. Subperiod IC has five structural levels. The houses consisted of courtyards, living rooms and rooms for storage. Amongst the finds of this subperiod, a 21-cm long spearhead and a bull-shaped seal, both of bronze, and an unfinished button-shaped seal in stone deserve special mention.

Three radiocarbon dates give chronological brackets for Subperiods IB and IC (Possehl 1990:38). Of these, the one relating to Subperiod IB (BETA-18843) yields the calibrated date of 2598 BC. The other two, for Subperiod IC, are about 2500 BC (BETA-18842), (BETA-18844). These pre-Mature Harappan strata antedated the middle of the third millennium BC.

Subperiod ID shows a transitional stage towards the Mature Harappan and occupies the same position in the cultural development as do Amri IIC or the transitional levels of Kot Diji. Many pottery shapes and painted designs of this subperiod may have contributed to the ceramic repertoire of the subsequent Mature Harappan civilization. For example, a dish-on-stand decorated with a fish motif, a jar bearing the fish-scale design and a comb like pattern in the Kot Dijian style, intersecting motifs, humped bulls, pipal trees, etc.

In the Subperiod ID many large-sized mud-brick structures including platform and a 7.75-m wide wall which was traced in all small trenches to a considerable length were also found. In this context it may be mentioned that mud-brick platforms become quite a characteristic feature of the monumental building of the Mature Harappan culture.

Period II yields typically Mature Harappan pottery, both in terms of shapes and painted designs. Some of the pots also bear characteristic signs of the Indus script. We should note here an enigmatic phenomenon, viz. that practically all the structures of Period ID had been 'heavily burnt and the walls turned red due to heat' (Jarrige 1989: 64).

Rana Ghundai

Located in Loralai district, Rana Ghundai was excavated by Ross. Pigott (1950) classified the deposits into five periods. Period I itself was characterised by flint blades, points and eyed needles of bone which included those of the cattle (*Bos indicus*), sheep (*Ovis vignei*) and ass (*Equus assinus*). There were four teeth which Ross thought were of the true horse (*Equus caballus*). The distinguishing feature of Period II was the appearance of a wheel-turned red ware, often slipped and painted in black pigment with characteristic motifs like humped bull and black bucks. Mud walls with stone-foundation were also noted. Period III is relatively a longer one. The site has not yielded any clearly identifiable remains of the Mature Harappa culture.

Dabar Kot

Measuring over 150 x 135 m on plan and rising to a height of nearly 35 m above the surrounding plains of the Thal river, Dabar Kot is certainly one of the most impressive sites in Baluchistan. Discovered towards the end of the last century, partly excavated by Stein in 1927 and revisited by Fairservis a little over two decades later, it has yielded a lot of typically Mature Harappan material from the middle levels.

Damb Sadaat

About 15 km west of Kile Gul Mohammad lies Damb Sadaat which carries forward the story of the former site (Fairservis 1956). Thus, the earliest levels of Damb Sadaat (Period I) yielded a variety of painted pottery, e.g. black and brown designs on buff surface, white designs on black surface, and polychrome designs on black surface, and polychrome designs involving simultaneous use of black, white and red - all going under the generic name of Kechi Beg ware, derived from a site located on the Quetta-Sibi road. Such wares appeared at Kile Gul Mohammad in Period IV and hence a continuity from that site. The houses were made of mud bricks on stone foundations. Stone and bone tools were still in use though no copper objects have been found so far.

The succeeding period, DS II, witnessed another kind of pottery, with plain or slipped buff surface painted over in black colour with floral, faunal and geometric motifs - known as the Quetta ware. Also present were the Quetta wet and Faiz Mohammad grey wares. The houses continue to be made of mud bricks on stone foundations. Period DS II also yielded copper objects inclusive of a dagger, alabaster vessels, a compartmented seal, clay and shell bangles, bone and ivory beads, human and animal figurines and house-models of clay painted in the Quetta ware style.

Though no radiocarbon dates are available for the site, this last period may well belong to the middle of the third millennium BC, contemporary with the Mature phase of the Harappan civilization.

Nal, Kulli and Nindovari

Nal, located in Jhalawan district, was excavated by Hargreaves in 1925. The burials are mostly in pots but a few in separate graves as well. These latter lay flexed in a mud-brick chamber. The pot-burials were fractional. The Nal ware is of fine fabric, wheel-turned and well fired. Motifs include: geometrical motifs such as stepped, trapezoidal and zigzag panels; faunal motifs include ibex, gazelle, scorpion, fish, birds and humped bull and some floral motifs. The total effect of

these colours and designs is spectacular. The shapes included amongst others, tapering, wide-mouthed bowls or straight-sided bowls, mostly with a ring-base, squat pots with bulged sides, canister-like vessels with a constricted mouth etc. The antiquities associated with the Nal complex included: long, narrow, crescent edged axes and seals of copper; a finger-ring of silver; querns, mullers, pounders, celts, etc. of stone; beads of agate, carnelian and lapis lazuli; bangles of shell; and terracotta figurines mostly of the humped bull but also one of the ram.

Characteristic of the Kulli site were terracotta figurines: painted humped bull and female figurine with beaked nose, appliqué eyes, arms placed akimbo, and finishing off below the hip. The pottery was plain as well as black-on-red with an elevated bull with large rounded eyes and long horns acquiring the type-name of 'Kulli style'.

Mehi was also dug by Stein (1931: 154-63) and brought to light something unusual, viz. cremation burials, the bones lying generally in urns. The funerary assemblage included, besides pottery, bangles, hairpins and mirrors, also copper beads of semi-precious stone, terracotta female figurines, etc.

Nindowari was excavated by Casal (1966: 10-21) who discovered a large number of stone structures. The site belongs essentially to the Kulli culture, as signified by the occurrence of typical Kulli style pottery and terracotta figurines. However, most important was the occurrence of two seals with typical characters in the Harappan script with the unicorn motif. Nindowari was contemporary with the Mature phase of the Harappan civilization and had trade contacts with it. There were regional manifestations characterised by individualistic pottery and terracotta figurines - such as those of Zhob, Nal, Kulli etc. None of these cultures were the precursors of the Harappan civilization.

Gumla

Gumla near Dera Ismail Khan was excavated by A.H. Dani (1970-71). It yielded the remains of six occupational periods. Period I (from bottom upwards) yielded parallel-sided blades, burins, scrapers, awls, etc., besides heavier stone equipment in the form of saddle querns, mullers and pestles.

Period II, however, heralded newcomers to the site. Not only did they use pottery but also copper/bronze of which an antimony rod was found. The pottery was wheel-turned plain and painted. Female figurines show a skilful modelling of the buttocks. Amongst the animals both humped and humpless bulls were represented.

By the end of Period II the site seems to have been abandoned for some time, as indicated by the intervening sterile layer. These new settlers arrived with a different cultural assemblage. For the first time mud-brick structures were encountered. The size of the bricks was 28 x 13 x 7 cm, showing an approximate ratio of 4:2:1 - distinctive of the subsequent Harappan culture.

The terracotta female figurines have broad hips merging into an undifferentiated short and flat leg-block, extending at right angles to the former. Also found were two antimony rods and a nail-pairer of copper/bronze and a variety of terracotta bangles sometimes decorated with incised zigzag designs. There is a layer containing ash, charcoal, potsherds, etc., between Periods III and IV. Period IV has identifiable Harappan elements, such as perforated vessels, triangular cakes, toy-carts, solid wheels - all of terracotta, cubical weights, etched beads of carnelian and disc-shaped beads of paste. The large podium of mud-bricks reminds us of the podia encountered at many of the Mature Harappan sites. Many elements of the preceding period also continued, indicating a clear existence of the two trends.

Period V, represented by graves containing cremated human and animal bones, including horse, followed Period IV. A layer of burnt earth, ash, etc. caps Period IV and the excavator thinks that it is the grave-people who destroyed the Harappan settlement. Period VI is represented by graves with flexed burials associated with iron.

Rehman Dheri

Located north of Dera Ismail Khan, Rehman Dheri covers an area of about 540 x 390 m. Excavations carried out by F.A. Durrani (1981a, 1981b, 1988; and Durrani *et al.* 1991) revealed three periods of occupation, Periods I, II and III from bottom upwards.

Despite some affinities with Kot Diji, the pottery represented predominantly a local tradition which included ring-based bowls and cups of fine red ware.

A very noteworthy find from Period I was a roughly squarish (3 x 2.7 cm) ivory seal, with two holes along one edge evidently for suspension. On one of its sides have been engraved two mountain goats, along with three symbols. There are four radiocarbon dates which place Period I, around 3000 BC, if not earlier. From Period II of Rehman Dheri came typical Kot Dijian pottery. The material from Period III gets closer to the typical Harappan artefacts.

The uppermost levels of Rehman Dheri (Period III) have yielded more evolved Kot Dijian Pottery with some elements anticipating Mature Harappan traits.

Sarai Khola

Sarai Khola has a mound of about 600 x 300 m on plan and containing about 6 m of occupational deposits. Four cultural periods, numbered I-IV from bottom upwards, have been identified by excavator, Mohammed Abdul Halim (1970-71 and 1972). The tool-assemblage of Period I comprised polished stone axes, chert and flint blades and other microliths and bone points. The pottery made from thick to medium grained clay had a burnished brown surface. The types included pans and bowls, the latter having mat-impression at the base, similar to the Neolithic culture of Burzahom.

Without any break in occupation, Period II is marked by the appearance of a new set of people who brought the Kot Dijian ware. The main antiquities of this period comprise human and animal terracotta figurines, toy-carts and wheels, beads of lapis lazuli, agate and carnelian and bangles. The terracotta seated female figurines are similar to those found at Gumla and Rehman Dheri. No copper object was found in the Period I. Period II yielded over a dozen copper/bronze objects comprising spearheads, needles, nail-parers, antimony rods with rolled ends, pins, rings and bangles. There are five radiocarbon dates for this period, giving a mid-III millennium BC bracket.

Harappa

Different parts of the site at Harappa were named by Vats as: Mound F, on the northern extreme, Mound AB, the citadel mound south of Mound F; Mound E, to the southeast of Mound AB, and so on. The HARP (The Harappan Archeological Research Project) excavators have divided the occupation strata in Mound E into five periods, as given below.

In the northern part of Mound AB, Meadow and Kenoyer have discovered a 3-4 m thick deposit of Period I in which the pottery is essentially handmade. It is a red ware bearing designs in black pigment, often with the addition of white. The motifs include the intersecting circle

which becomes subsequently a characteristic feature of the Mature Harappan. The houses are oriented north-south and east-west and the bricks too have a set ratio of 4:2:1. There are micro-beads of glazed steatite, copper objects, bone tools and blades made from Baluchistan chert. Long-distant contact (trade) is further indicated by the presence of marine shells from Makran coast.

Period II has been distinguished from Period I because of a major structural event, viz. the construction of a peripheral wall in the north-western part of Mound E, oriented at an angle of 10° west of due north (for all practical purposes a north-south orientation). While the pottery and other objects of Period I continued into Period II, a noteworthy addition was that of terracotta cakes which became a distinctive Harappan trait. There is no break between Periods II and III. The use of kiln-fired bricks which became the hallmark of the Mature Harappan civilization marks Period III. Period IV was a transitional stage towards Period V, related to the Cemetery H Culture.

Regarding the chronology, Kenoyer and Miller (1999) say, "We have chosen to use the chronology defined by Shaffer (1992), which is presented in Table 5.1 (see also Table 4.2 given below-DPA) along with its correlations to other more widely used but less precisely defined chronologies. As defined by Shaffer (1992), the Indus valley tradition includes all human adaptations in this greater Indus region, from around 6500 BC until 1500 BC and later. This Tradition can be subdivided into four Eras and several Phases. The Early Food Producing Era (c. 6500-5000 BC) as defined at the site of Mehrgarh, sees the beginning of domesticated plants and animals, as well as the first find of copper in the form of a bead (Jarrige 1983). The Regionalization Era (c. 5000-2600 BC) follows with the development of distinct agricultural and pastoral-based cultures associated with various specialized crafts, including the melting and working of copper. During the Integration Era, which is represented by the Harappan Phase (2600 BC-1900 BC), we see the cultural, economic and political integration of the vast region defined above".

Table 4.2 Provisional prehistoric chronology of Harappa
(after Kenoyer 1997)

Periods 1A and 1B Early Harappan (Ravi-Hakra Phase)	c. 3300-2800 Cal.BC
Period 2 - Early Harappan/Harappan Transitional (Kot Diji Phase)	c. 2800-2600 Cal.BC
Period 3 - Harappan Phase	
Period 3A	c. 2600-2450 Cal.BC
Period 3B	c. 2450-2200 Cal.BC
Period 3C	c. 2200-?1900 Cal.BC
Period 4 - Harappan/Late Harappan Transitional	no dates
Period 5 - Late Harappan	?-1700 Cal.BC

The Harappan Phase of the Integration Era represents the first urban civilization in southern Asia and the earliest state-level society in the region (Jacobson 1986; Kenoyer 1991; Meadow 1991). Recent studies suggest that the Indus state was composed of several classes of elites who maintained different levels of control over the vast regions of the Indus and Ghaggar-Hakra valley. The rulers or dominant members in the various cities would have included merchants, ritual specialists and individuals who controlled resources such as land, livestock and raw materials.

Although these groups may have had different means of control, they shared a common ideology and economic system as represented by seals, ornaments, ceramics and other artefacts. This ideology would have been shared by occupational specialists and service communities, who appear to have been organized in loosely stratified groups (Kenoyer 1991). Political and economic integration of the cities may have been achieved through the trade and exchange of important socio-ritual status items, many of which would have been produced by specialized artisans using complex pyrotechnologies to manufacture metal objects, agate beads, steatite seals, stoneware bangles, elaborately painted and specialized ceramics, and faience objects (Kenoyer 1992a).

Kot Diji

Located near Mohenjodaro, on the opposite side of the Indus, Kot Diji was excavated by F.A. Khan (1965:11-85). It revealed extensive remains of the Kot Dijian culture. Layer 3A gives a mixed deposit of Kot Dijian as well as Mature Harappan cultures, while layers 1, 2 and 3 and various subdivisions of 2 and 1 represented the Mature Harappan culture. The 5-m thick occupation of the Kot Dijian culture shows within itself a kind of evolution.

The Kot Dijian houses were made of mud bricks of the size 38 x 19 x 9 cm. It shows the same ratio of 4:2:1 which became the characteristic feature of the Harappan bricks. The most significant is the fact that the Kot Dijians did have a fortification-wall around their settlement, which at places is extant to a height of about 4.5 m. Four radiocarbon dates place Period I at Kot Diji between c.3000-2500 BC. The Kot Dijian occupation was capped by a layer containing ash, charcoal, burnt earth, etc. Metal is represented only by a fragmentary bronze bangle.

Amri

About 130 km south from Mohenjodaro is the well-known site of Amri. The site was excavated by J.M. Casal. He divided the total deposits into five periods: Amri IA-D, Amri Culture; IIA-B, Intermediate; IIIA, Mature Harappan; IIIB, transition; IIIC, Mohenjodaro upper levels; IIID, Jhukar; IV, Jhangar; and VA and B, Mediaeval (Casal 1964).

The subdivisions in Period I are largely based on pottery. The use of black and red paint is a conspicuous feature of the Amrian pottery and seems to have its ancestry in the hilly cultures of Baluchistan where bichromy and polychromy were the general fashion in the fourth millennium BC. In the earlier levels of Period I there is some handmade pottery as well. The other finds from Period I included chert blades, stone balls, bone tools, terracotta and shell bangles and a few pieces of copper indicating a limited use of metal. Towards the end of the Period ID there appeared a few pottery-shapes as well as painted designs which are normally associated with the Harappan civilization. By Period IIIA the Amri pottery almost disappeared and the Harappan completely took over the scene.

Radiocarbon dates place the beginning of Period I at Amri to around the middle of the fourth millennium BC.

Balakot

Some 88 km from Karach, Balakot occupied an eminent position as a seaport during the Harappan times. It has, however, brought to light a still earlier culture which the excavator, G.F. Dales, has termed Balakorian (Dales 1979 and 1981). This culture has an intermixture of polychrome Nal and Anjira pottery along with the Amrian. Four radiocarbon dates place the Balakorian culture

in the fourth millennium BC, extending into the third and the Harappan occupation to mid-third millennium BC.

Hakra-Ghaggar basin

In the Hakra Ghaggar area, there was a considerable increase in the size of the Mature Harappan settlements in the region. Ganweriwala was 81.5 hectare in area almost the same size as that of Mohenjodaro. Secondly, at many of the sites a clear separation of the residential area from the industrial one has also been noted, signifying a greater emphasis on industries. There also seems to have been a sort of population explosion during the Mature Harappan period. Compared to only 40 Early Harappan sites there were as many as 174 in the Mature Harappan times (Mughal, 1990). Geographically, Ganweriwala seems to be the epicentre of the Harappan civilization.

Kalibangan

Kalibangan on the bed of the Ghaggar, is in district Hanumangarh, Rajasthan. It has a larger mound on the east and a relatively smaller one on the west. Altogether the three mounds have a periphery of about 1.5–2 km. Kalibangan Period II is typically Mature Harappan and Period I, is Early Harappan (Lal 1997).

The walls of the houses and the street were laid out along the cardinal directions. The houses were made of mud-bricks which measured 30 x 20 x 10 cm. Bricks were not in the same proportion as those in the Mature Harappan times, yet follow the 3:2:1 ratio.

Even the pre-Mature Harappan settlement was fortified. Oriented more or less along the cardinal directions, the fortification-walls made a rough parallelogram on plan, the eastern and western sides measuring respectively 250 and 240 m.

Period I at Kalibangan indicated that the furrows of a field ran in two sets of rows, cutting each other at right angles. Thus, while one set was laid out east-west, the other was north-south. Even today, the practice is to grow horse gram in the narrow furrows and mustard in the wider ones.

Even from the limited excavated area, Period I yielded an axe, a *parasu* and a bangle of copper/bronze. It is interesting to note that even today the *parasu* hafted on to a wooden handle is used in parts of Rajasthan for cutting scrubby bushes to obtain firewood.

The pottery from Period I of Kalibangan calls for special attention, since it is representative of most of the pre-Mature Harappan settlements in north-eastern Rajasthan and Haryana. On the basis of the fabrics, a sixfold division has been made, viz. A-F. Of these, Fabric A was the most characteristic and accounted for the bulk of the pottery.

Towards the end of the fifth structural subperiod of Period I there occurred an earthquake, indicated by the faulted strata and cleft walls. This perhaps is the earliest archeologically identified earthquake in India, perhaps even in the world.

Banawali

It is located about 120 km from Kalibangan in district Hissar, Haryana, on the right bank of the Sarasvati. The ancient mound, rising to a height of about 10 m above the surrounding plains covers an area approximately 400 x 400 m. Excavations carried out by R.S. Bisht (1982, 1984, IAR-1986-87) have brought to light three cultural periods: I pre-Mature Harappan; II, Mature Harappan; and III, post-Mature Harappan.

Period I: The houses, made of mud bricks, were laid out along the cardinal directions, i.e. east-west and north-south. Like those of Kalibangan the earliest settlers at Banawali too made their bricks in the ratio of 3:2:1. Banawali I has also yielded square bricks, measuring variously 24 x 24 x 8 or 27 x 27 x 5 or 30 x 30 x 10 cm.

Within the houses there were ovens and fire-pits. In one case, a circular fire-pit was outlined with mud bricks. Circular pits for storage of grains have also been reported.

Period I of Banawali yielded an arrow-head and a fish-hook of copper, beads variously of carnelian, lapis lazuli, steatite, and clay, bangles of shell, faience and clay and two spatulae and a handle of bone. A stone weight, perhaps the first of its kind weighed 87.855 grams. The entire settlement was planned and constructed *de novo*. The bipartite layout which the Harappans adopted was introduced during this subperiod. The Period I culture of Kalibangan and Banawali was very widely spread in north-eastern Rajasthan, Haryana and Punjab as demonstrated by the list of 136 sites of pre-Mature Harappan sites published by J.P. Joshi *et al.* (1984). Since then many more sites have come to light.

Kunal

Kunal, in district Hissar, not only has the pre-Mature Harappan pottery but also an extraordinary yield of a variety of ornaments in gold and silver (Khatri and Acharya 1995). These include spiral bangles, 'crowns' and discular bead with axial perforation - all of silver and over twelve thousand beads variously of carnelian, agate, lapis lazuli, steatite and shell. All these speak volumes for the trade and affluence of the people even in the pre-Mature Harappan times. In the context of trade, one might note the occurrence of seven seals, six of steatite and one of shell. These seals do bear motifs, mostly geometric, but no inscription, which seems to have been a Mature Harappan feature. However, the site did not yield any Mature Harappan assemblage.

Three radiocarbon dates place the pre-Mature Harappan occupation at Kunal in the first half of the third millennium BC.

Dholavira and other Gujarat sites

The lowest 60-70 cm thick deposit at Dholavira in Kutch and other sites has yielded pottery some of which is different from the Mature Harappan. In these levels there is also ample evidence of copper-working. Further, a well established settlement is indicated by the presence of structures, of which, incidentally, the bricks were in the ratio of 4: 2: 1, the actual measurement being 36 x 18 x 9 cm (Bisht 1991). At Lothal in the riverine plains, sherds of micaceous red and black-and-red wares have been found in the lowest deposits both of which are non-Harappan, thereby pointing to an indigenous element (Rao 1979). Some of the radiocarbon dates for Rojdi in central Saurashtra (Possehl 1990: 44) take it before the middle of the third millennium BC about which time the Mature Harappan civilization appeared. In the western coastal area, Prabhas Patan (Somnath) has yielded the remains of what has been termed as the 'Pre-Prabhas Culture' which on the basis of radiocarbon dates, viz. 2911 BC and 2892 BC, seems to have antedated the Mature Harappan (Possehl 1990:41). Padri, in Bhavnagar District, has two radiocarbon dates, viz. 3048 BC and 3680 BC (calibrated; respectively nos. PRL-1785 and PRL-1787). Yet another noteworthy site in Gujarat to have yielded pre-Harappan remains is Nagwada.

With this prelude to the Harappan urbanisation, we discuss the metallurgy and archaeology of the Harappan phase in the next chapter.

CHAPTER 5

HARAPPAN METALLURGY

CONTENTS

- ARCHAEOLOGICAL BACKDROP AND COPPER TECHNOLOGY
- ORNAMENTS AND MIRRORS
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ARCHAEOLOGICAL BACKDROP AND COPPER TECHNOLOGY

The Indus civilization or Harappa Culture (named after the first discovered site, Harappa) is remarkable for its uniformity and standardisation in weights, measures, ceramics, architecture, town planning and in other arts and crafts. This uniformity appears all the more imposing when one considers that the culture extended over an area more than that of Pakistan today. What this uniformity reflects, whether it was an empire or a trading zone, can only be a speculation. But such uniformity, almost amounting to monotony, in a third millennium BC context is indeed unique. Recent studies, however, are bringing out a good deal of regional variation too (Agrawal 1986: 135).

To define the Harappa culture is not an easy task. The traits that originated earlier and the regional variations complicate the definition. Wheeler tried to define the culture by the alternative or accumulative presence of: (i) Indus seals (Figs. 5.1, 2, 3); (ii) Indus script; (iii) motifs like intersecting circles (Fig. 5.4), (iv) ceramic forms like goblets with pointed base, cylindrical pots with multiple perforations, jars with S-profile and dishes on-stand; (v) triangular terracotta cakes; (vi) kidney-shaped inlays of shell or faience; and (vii) certain beads, notably discoid with tubular holes. To these one may add town-planning (streets in grids, underground drains, fortified townships); brick dimensions in the ratio of 1:2:4; and typical shapes of copper artefacts like bent-bladed knives, double-edged razors, barbed triangular arrow-heads with holes (Figs. 5.5, 6, 7, 8, 25, 27, 29) etc.

The hallmark of the Harappa culture is town planning, though fortifications and some amount of planning are also evident both at Kot Diji and Kalibangan in the Early-Harappan levels. The

citadel, whether fortified with the lower town, or separately, was generally located in the west (except at Lothal). Houses, with rooms opening from three sides into a central courtyard, provided with water, drains, and latrines, are characteristics of the Harappans.

In the outlying areas, the classical Harappan tradition absorbed some local traits also. The mother goddess figurines and phalli of the Sind are absent in Rajasthan and Gujarat. At Lothal there are fire altars, but they are different from those of Kalibangan. At Kalibangan the tower platforms with fire altars, approachable only through a staircase, are unique in the whole of Harappan 'empire'. It seems that though uniform standards were imposed over artefacts of mass consumption and trade, local differences in culture and religion were not interfered with. The script and the language too may have showed regional variations, but nobody has looked into it so far. These local differences will come to the fore in the course of our discussion of individual sites.

As mentioned above, the Harappa culture was spread up to Suktagendor (Makran) in the west, in the east up to Alamgirpur (UP), Ropar in the north and Bhagatruv in south Gujarat. The uplands of Baluchistan, most of Uttar Pradesh and the south were out of its purview. Even the Indo-Gangetic divide does not have the Mature Harappan and local elements. The culture is mainly confined to the Indus valley and Saurashtra, including Kutch. There are a number of Harappan sites on the dry Ghaggar-Hakra system, which probably joined the Indus or the Nara in the past. In the light of this definition of the Harappa culture and its distribution, let us trace its origins.

Although the Harappa culture appears in a fully developed form, a closer look at it reveals that it had in fact derived a great deal from the antecedent cultures, so much so that Mughal terms the so-called Pre-Harappan cultures, 'Early Harappan'. Let us analyse the traits that the Harappan culture inherited from the preceding cultures.

It is remarkable of the Harappans that they had evolved a highly standardised system of weights and measures. Two systems of measures are in vogue: units and a long foot. A cubit was about 52 cm (52.5 to 52.8 cm) and the long foot 33.5 cm. Graduated scales have been reported from Mohenjodaro, Lothal and Kalibangan. The Lothal scale has divisions of 1.7 mm with decimal graduations. It may be pointed out that the *Arthashastra's angula* was 17.86 mm compared to 17.7 mm divisions on the Harappan scale.

The weights were made out of chalcedony, black stone etc. and took cubical forms. They followed a binary system (1, 2, 4, 8, 16, 32 up to 12,800) in the lower denominations. The traditional Indian ratio of 1:16 (Rupee=16 annas) seems to derive from this. The unit weighs 13,625 gm. Higher weights follow a decimal system with fractions in one-third. Accuracy of these weights all over the Harappan territory is remarkable indeed.

Rao reports a shell object (now also reported from other sites in Saurashtra) with four slits which was probably used to measure angles.

The tool repertoire of the Harappans shows a lack of warlike weapons. The types are simple. Neither the complicated mouldings of Mesopotamia nor the ornate designs of Chinese metalware (see chapter 10) were ever attained by the Harappan smiths. Most of the artefacts appear utilitarian. Except for two specimens of the dancing girls (Fig. 5.9), no human images are available in metal. But these animal figure examples (Figs. 5.10, 11, 12, 13, 14, 26) do show their competence in the lost wax (*cire perdue*) method of casting. Unlike the other Chalcolithic cultures of India, one has plenty of pots and pans in metal (Figs. 5.15, 18, 19, 20) here. The main tool types (Fig. 5.16, 17, 24) are: razors; leaf-shaped knives with incurved end; sickle blades with externally sharpened edge; chisels; spearheads; thin barbed arrow-heads; straight and circular saws; blade-

axes; mid-ribbed daggers; drills; and eyed needles. It may be pointed out that needles with eyes on the pointed ends, true saws, circular saws, and drills are Harappan contribution to the world of instruments. Shaft-holed axes are rather a rarity and must depict imports. One of the razors from Mohenjodaro was found wrapped in cloth (Fig. 5.21).

Discussing the nature of the Harappan tool repertoire, Wheeler (1968: 73) says, "In considering the possible implements of war, we may reject the simple chert blades which occur abundantly on all Harappan sites, as on many others of the same general period. But alongside these are found metal implements of which a majority may have been used equally by the soldier, the huntsman, the craftsman, or even by the ordinary householder, and are included in this section without prejudice. They are of copper or of bronze generally poor in tin, and include spears, knives, short swords, arrow-heads and axes. It has been suggested that small domed pieces of copper, each perforated with two holes, were sewn on to a garment and used as an equivalent to mail, but there is no supporting evidence and neither body-armour nor helmets (well known in Early Dynastic Sumér), nor indeed shields, can at present be attributed to the Harappans. Spears are invariably tanged and cannot clearly be distinguished from knives. Most of them are thin, flat, leaf-shaped blades which would buckle on impact and must have been stiffened by being set back between the split ends of the shaft, which would thus serve as a mid-rib. Sometimes two small holes near the base of the blade suggest a former binding for such a device. Rarely (in four instances) the blade has a slight median thickening, the section being diamond-shaped. Such reinforced blades are up to 18.5 inches in length and may rather represent short swords or dirks, a type of weapon for which there is no other evidence. They are from late levels, and have parallels of c. 2200-1750 BC in Syria and Palestine. The leaf-shaped spearhead is universal; no barbed blade has been found, although there is a clear illustration of a barbed spear on a Mohenjodaro seal, and a barbed spearhead from Ur has been cited in this connection.... Leaf-shaped knives may sometimes be differentiated from spears by having a slightly sinuous, recurved point, a Harappan peculiarity hardly ever found outside the Indus civilization, although one example is reported from Hissar III in north-eastern Iran. The appearance of a hafted knife is summarily indicated by a tiny graffito on a potsherd from the Great Granary.

"Arrow-heads are fairly numerous and are almost invariably of copper or bronze. They are thin and flat, with long, narrow barbs and no tang, resembling the swallow-tailed flint arrow-heads of Egypt and northern Iran. The metal type does not occur in Egypt or Sumer, but is found in Minoan Crete. On the other hand, flint or chert example are almost unknown in the Indus valley: exceptions are from Kot Diji and from Periano-ghundai in northern Baluchistan. Copper or bronze axes are flat, without the shaft-hole which had early developed elsewhere in Western Asia. They were presumably hafted in a split and bound handle. Some of the axe-blades are long narrow, with nearly parallel sides and may sometimes have been used in prolongation of the haft; others are short and relatively wide, with boldly expanded edge".

About the shaft-hole axes, Wheeler (1968) says that the general absence of the shaft-hole is the more remarkable in that the example of this superior method of hafting did on rare occasions reach the Indus. Two pottery models of shaft-hole axes are recorded from Mohenjodaro, recalling the occurrence of similar clay models as early as the al'Ubaid period in Mesopotamia; and a bronze example was found at Chanhudaro in a late Harappan Jhukar layer. More elaborate is a fine copper axe-adze from a late level at Mohenjodaro, of a type with analogies in northern Persia (Hissar IIIC, Shah Tepe, Turang Tepe), at Faskan and Maikop in North Caucasia, and, in miniature, under the foundations of the Anu-Adad temple at Assur, erected by the Assyrian

King Salmanassar III (859-824 BC), and in the B cemetery at Sialk about the same time. Farther west, the type is found in Crete (c. 2000-1900 BC), in the Balkans, and in the regions north of the lower Danube and as far afield as the Ukraine (perhaps towards the middle of the second millennium BC). The dating of Hissar IIIc and the relevant 'Astrabad Treasure' of Turang Tepe is disputed; the weight of opinion is at present on the side of a terminus at or shortly after 2000 BC, but some writers would make it up to a thousand years later. It may be agreed provisionally to ascribe the Mohenjodaro axe-adze to an unresolved date in the second millennium and, with Heine-Geldern, to regard it as an intrusive type initially popularised in the Caucasian or South Russian region. Its associations combine to suggest that its dispersal may have been incidental less to trade than to the widespread folk-wandering of the millennium (Wheeler 1968).

Animal copper figurines of dog, swan, elephant and bull were also cast in miniature.

Regarding their metallurgical skills it may be pointed out that the Harappans could smelt even sulphide ores, though oxide ores were commonly used. Large quantities of oxide ore were found from a house at Mohenjodaro from a brick-lined pit. The similarity in the trace impurity patterns of the Harappan artefacts and the copper minerals of Khetri mines may indicate its exploitation. But so far the actual copper workings in the Khetri belt have not been dated beyond c. 1000 BC.

Out of the 177 artefacts analysed earlier from Mohenjodaro and Harappa, only 30% were alloyed. Tin alloying ranged from 1-12%; arsenic alloying 1-7%; nickel alloying 1-9% and lead 1-32%. Tin bronzes were more common than any other alloys. The Harappans knew the techniques of sinking, 'rising', 'running-on', cold work, annealing, riveting, lapping, closed casting, *cire perdue* etc.

The Harappan cities are marked by a remarkable planning unheard of elsewhere in the third millennium BC. The alignment of buildings and fortification walls was on cardinal directions. The streets were laid at right angles to each other. A well designed system of drains leading from individual houses led to public soakage jars and underground drains below the streets. There must have been a civic staff to clean the sewage regularly.

ORNAMENTS AND MIRRORS

The following description of the Harappan ornaments is based on Kenoyer & Miller (1999). The use of copper as a form of ornament has a long history in the greater Indus region and can be traced back to the early levels at the site of Mehrgarh, where there is evidence for a single copper bead from the Neolithic levels (Period IB) at c. 6000 BC (Jarrige 1983, 1985b). Several copper ornaments have been reported from the subsequent layers (Jarrige 1983), but these objects have not yet been analysed, so details of composition and manufacture are still unknown.

Deposits of Period III at Mehrgarh (4000-3500 BC) also contained corroded fragments of rods and pins. Two double spiral headed pins show that the discovery of such pins in the later Harappan phase sites no longer indicates connection with the much later Namazga III sites in the western and northern highlands. A fragmentary copper object from one grave of Mehrgarh Period III may be a compartmented seal, again indicating the presence of these objects in a context that predates the Quetta-Namazga III complexes (Jarrige 1985b).

The excavations at Mehrgarh and other sites of the Regionalization Era provide clear evidence for the gradual increase in importance of metal between the Early Food Producing and the Regionalization Eras. During the Harappan phase of the Integration Era, it is evident that metals supplement rather than replace the earlier materials used to manufacture ornaments (Table 5.4). In fact, many metal ornaments are copies of beads, pendants, or bangles made in non-metal

materials. There are some unique new types of metal ornaments, however, specifically those that incorporate gold, silver, and electrum. Metal also comes to be used in composite ornaments with other valued or symbolic materials, such as faience, various coloured stones, and shell.

At present, the best clue we have to the role of metal ornaments in Indus society is their archaeological context. Unlike contemporaneous sites in Mesopotamia, almost all of the complete ornaments (*e.g.*, necklaces and belts) found at Harappan phase sites have been recovered from hoards rather than from burials. Fentress (1977) tabulated the metal objects from Mohenjodaro and Harappa that were found in hoards, versus those found in non-hoard contexts, including burials (Table 5.5).

Although Fentress' table needs to be updated and include other sites, it presents some noteworthy patterns. Copper/bronze ornaments as well as copper/bronze tools have been recovered primarily from non-hoard contexts. In contrast, gold and silver ornaments and silver vessels have been found almost exclusively in hoards. It is interesting that copper/bronze vessels have been found almost equally in hoard and non-hoard contexts.

When considering the distribution of ornaments, it is thus necessary to discriminate between copper/bronze and metals such as gold and silver. Gold and silver ornaments have been found stored in ceramic, copper, or silver vessels that appear to have been deliberately hidden away. Some of these hoards include broken ornaments and melted lumps of gold or silver that would undoubtedly have been remelted and made into new ornaments. The hoards often contain numerous stone beads made from agate, carnelian, jasper, turquoise, and other varieties of coloured stones.

Copper beads and spacers are also included with some of the hoards (*e.g.*, Allahdino; Fairervis: personal communication), but copper ornaments have primarily been recovered in non-hoard contexts, such as in the debris accumulating in the streets or habitation areas, or in some of the burials. Out of 168 total copper/bronze ornaments reported, 130 were found in non-hoard contexts and only 38 were found in hoards, generally in association with gold and silver ornaments. The gold and silver ornaments found in non-hoard contexts are usually tiny beads or gold foil fragments that were probably lost in the muddy streets or courtyards.

Although very little metal was buried with the dead, burials, like hoards, provide a context in which metal ornaments were intentionally placed by the Indus peoples. Metal objects found in burials are almost all of copper/bronze, and include mirrors, finger rings, bangles, and occasional beads. In one instance three gold beads were found, strung together with three stone beads. While the mirrors are invariably placed with female burials, the other metal ornaments have been found with both male and female individuals (Dales and Kenoyer 1989). It should be noted that no utilitarian copper/bronze tools have been found in the burials.

The occasional pilfering of burials (see below) cannot be used to explain the low incidence of metal in undisturbed burials, especially the absence of elaborate gold and silver ornaments. Other ornaments that are noticeably absent are those made from exotic materials or involving complex production techniques, *e.g.*, carnelian, faience, or stoneware. This pattern suggests that ornaments which represented wealth or status were passed on from generation to generation and recycled, much as is done today in the subcontinent (Kenoyer 1992b).

The presence of mirrors in the burials is intriguing, as they were made of a considerable amount of metal that could have been recycled. Metal mirrors are a new object during the Harappan phase, as mirrors were not previously made in any material, either polished stone or metal (Table 5.4). Perhaps mirrors were needed by women in the afterlife, or the personal use of a mirror

made it an object that could not be passed on to another individual at death. However, mirrors are not found in *all* female burials. One possibility is that such beliefs may have been important to certain groups within Harappan phase communities, while others held different beliefs. However, another possibility is that this difference may reflect looting by grave diggers. Many of the burials recently excavated at Harappa were disturbed by Harappan grave diggers in the course of digging pits for later burials, and shell bangles and copper mirrors were generally missing from the disturbed female burials (Dales and Kenoyer 1989). It is interesting to note that, in contrast to the Harappan graves, the Chinese and Japanese graves were far richer in grave goods especially in bronze objects. From one Yayoi grave alone 25 bronze mirrors were discovered. Unlike the Indus Civilization, metal objects were symbols of power in China and Japan (see chapter 10).

The fact that precious metal vessels and ornaments have been found primarily in hoards, suggests that, unlike copper/bronze metal objects, they were used more overtly to define wealth, status, and power. The types of ornaments depicted on figurines may represent gold, silver, and stone ornaments that had symbolic as well as ornamental value. However it is curious that unlike Mesopotamia or Egypt, the Indus terracotta or stone figures are never depicted holding metal tools or weapons as symbols of status or power. The only pictorial or glyptic representation of the use of weapons or tools is seen in the pictographic signs of the undeciphered Indus script, or in narrative scenes on seals or moulded tablets (Kenoyer & Miller 1999).

About the Harappan ornaments, Lal (1997:167-68) notes, "Of gold, no vessels, even tiny ones, were made, evidently because of its rarity and cost, however, ornaments were frequent. These included a variety of beads - micro-beads, barrel shaped ones, some flat and discular with axial holes, amulets, pendants, rings, broaches etc. One of the spacers found at Lothal has ten holes, indicating the same number of strings in the necklace concerned. Thin, elongated, conical pieces with a hole near the thinner end may have been ear-pendant of the type used even now in India. However, no less interesting is a hollow conical ornament which is even today worn by rural womenfolk in Rajasthan and Haryana, in the middle of the upper part of the forehead where the hair parts sideways. It is known as *chauk*. Attention may also be drawn to the circumstantial evidence regarding the occurrence of a small, thin, discular plate with two perforations on a margin. It was found at Lothal on an altar where an animal had been scarified and may thus have had some ritualistic significance. In this context, the excavator (Rao 1985:634) reminds us of the ornament worn on the forehead by the famous 'priest' from Mohenjodaro".

After this general discussion of the Harappa culture and its material assemblage, we would mainly confine ourselves to copper-bronze artefacts discovered at the main sites and will not go into details of the cultural milieu of individual sites.

Before we go into the individual sites, we summarise some new evidence about the Harappan pyrotechnology that Heather Miller (1993:501-7) has collected.

PYROTECHNOLOGY

Heather Miller has done intensive research on pyrotechnology. We have made liberal use of her writings here. For discussion on pyrotechnology, see chapter 3.

Summing up Kenoyer & Miller say, "It is highly unlikely that copper processing was not being carried out in these large cities and in smaller settlements, but future research is needed to recover the types of indicators needed to define different stages of metal processing" (Kenoyer & Miller 1999).

The problems of possible sources of the Harappan copper have been discussed in chapter 2.

Mohenjodaro

Miller reports, "While ingots, mis-casts, semi-finished objects and metal fragments from various excavation areas are listed in Marshall (1931:485), the only non-metal evidence for metal processing from Marshall's excavations is a single fragment of crucible with adhering slag—unprovenienced and unnumbered (Marshall 1931:485). The preponderance of Mackay's data are also end-products, again scattered in different areas but predominantly found in DK Area G (Mackay 1937-38). The most important concentration of metal processing remains is in block 1, house 6 (Mackay 1937-38, I:41), although there were also 3 ingots from block 2 (Mackay 1937-38, I: 451). The block 1 finds include 3 mis-cast copper objects; 2 vitrified kilns; and a rectangular pit containing 'a quantity of copper ore in small pieces' and a small piece of lead (Mackay 1937-38, I: 452, 49-50, 54, successively). The mis-casts and the pit with ore are both from room 51, but the two kilns were in room 33. These are not contemporaneous finds, however, but are from two different periods. The pit is from Intermediate I phase, when rooms 51 and 52 were one room; the mis-casts and the two kilns are from Intermediate II phase.

"Thus, none of these finds are from the same temporal and spatial context. Additionally, there is no evidence that the two kilns were used for metal processing, and after an initial suggestion (Mackay 1937-38, I: 452), Mackay himself states quite firmly that they were not for metal processing (Mackay 1937-38, I: 41, 50), and that there are no metal processing furnaces from Mohenjodaro (Mackay 1948). In sum, we are left with a 'quantity' of copper mineral and no evidence for smelting it. The ingots, mis-casts and semi-finished objects indicate that copper-alloy processing was done at Mohenjodaro at least fabrication, and probably melting - but we do not know exactly where".

It is relevant to note here the summary of the evidence of local manufacture in Vats' report (1940) given by Chakrabarti & Lahiri (1996: 50), "Only the presence of arsenic/arsenic-rich minerals is attested to and includes a piece of yellow arsenic (*hartal*) in Sq K 12/14, Mound F (Vats 1940: 80) and a small lump of lollingite found in 'jar 277' the contents of which have been listed earlier. The several pieces and bits of slag found at Harappa are in general contextually associated with post-cremation urns (cf. Lahiri 1990: 413) and not with metalworking or furnace remains. The evidence for secondary manufacture is as follows: (i) Crucibles: a shallow earthenware crucible, oval at the base and with straight sides (Sq P24/9, Mound AB; Vats 1940: 150) and a fragmentary earthenware crucible found in Mound F, near a furnace "whose contents show that it was used for melting bronze" (Vats 1940:471, note 1). (ii) Unfinished and unworked objects: the most important examples are from 'jar 277', the contents of which have been previously mentioned. In addition, attention may be drawn to the numerous pieces of copper weighing about 2 lbs (Sq Q24/3 and 4, Mound AB). (iii) Furnaces and metalworking areas: Vats considered the possibility of metalworking being done in a number of furnaces which were discovered in Mound F. These furnaces showed three types. There is a pottery jar furnace, three-fourths of which is embedded in the ground, showing contact with fire. Two cylindrical pits dug in the ground have been found with evidence of fairly intense firing. One of them, furnace Fa, is 3 ft 4 inches in diameter, with a depth of 3 ft 8 inches. There is evidence of slanting flue, which served as an air channel for the furnace. A part of the vaulted roof of the furnace was also found lying inside it, and there were flues in this vaulted roof probably as outlets for smoke or as gaps to be covered when the heat had to be conserved. Thirdly, there are 13 pear-shaped pits dug in the ground, often with a column. According to Vats (1940: 470-74) these

were used for metalcrafting". (see also chapter 3.)

Miller analyses the pyrotechnological evidence (details in chapter 3) from Harappa and says, "The only claimed metal processing area from the early excavations is Vats' furnace from Mound F, trench 4 - the area of the workmen's quarters, stratum II (Vats 1940, I: 470). It was split lengthwise, and only half of the kiln was found by the excavators. This kiln was very heavily vitrified, to the point where parts of the surface ran in pencil-like formations. The sole item of evidence that this kiln was used for metal processing, however, is a footnote in Vats that a crucible fragment with traces indicating that it had been used for bronze casting was found 20 feet south of the kiln (Vats 1940, I: 471). I should note that some 16 kilns were found in this area, and no analyses of the material from this crucible were ever published. After extensive re-examination of this kiln, in conjunction with conservation efforts over the past two seasons at Harappa, I can conclusively say that there is absolutely no evidence that this kiln was used for any kind of metal-working, although it definitely was employed for the generation of high heat. Fa was the only kiln Vats ever claimed was used for metal processing of the 16 kilns on Mound F (Vats 1940, I: chapter 18). Thus, contrary to widely disseminated literature, particularly secondary sources, there are no excavated metal processing kilns from Harappa".

Miller clearly distinguishes between smelting and melting at a site. She says, "... of the published claims for copper-alloy metal processing areas at Mohenjodaro and Harappa, two do not represent metal processing at all, and two represent melting of copper-alloys, or possibly small-scale crucible smelting (at Mohenjodaro). There is no evidence for large-scale furnace smelting at either site".

Miller points out that much of the literature implies or states that smelting of copper took place at Mohenjodaro and Harappa. "I found this surprising and rather unlikely, given the distance from any ore source. If the assemblages from Mohenjodaro or Harappa were indeed from smelting, this would be a very exciting find, because bringing ore such a distance to be smelted offers tantalising hints about control of production, control of technological knowledge, the status and power of metalsmiths, and/or the sophistication of Indus tradition metal processing in comparison to that of groups living nearer the ore sources" (Miller 1993). She emphasises that the types of copper alloy processing slags from both Harappa and Mohenjodaro are in all cases indicative of melting, or possibly very small-scale crucible smelting operations.

Miller complains that less attention has been paid to melting and fabrication field sites, which are admittedly much less visible. "The level and type of control of the Indus tradition metal processing industry is a complete unknown; as a major craft industry, investigation of such control is important for general theories about control of production. Metal industries, for all stages of production, are usually assumed to be complicated technologies highly controlled by one group or another. In contrast, Hauptmann has suggested that copper smelting at Shahr-i-Sokhta was done on a household basis, and was a widely known technology, not a specialist industry (Hauptmann & Weisgerber 1980: 56). Hauptmann's hypothesis was based on the wide distribution of copper by-products within residential areas of the site, and he assumes easy access and availability of copper ore. For this part of Iran, these assumptions are not much different than assumptions made about ease of access to clays in the discussion of ceramic production". This brings to mind the still extant tradition of itinerant smiths that cater to the needs of both urban and rural people.

Miller however cautions, "I am not suggesting that Indus tradition copper processing was a household-based operation - for one thing, the distribution of slags at Harappa and Mohenjodaro

is quite discrete. I am suggesting, however, that we can question our assumptions about the relative complexity and 'secrecy' of copper processing technology, particularly as different stages and types of processing may be differently classed". (For pyrotechnology see also chapter 3.)

COPPER ARTEFACTS FROM MAIN SITES

- Mohenjodaro
- Harappa
- Chanhudaro
- Lothal
- Rangpur
- Kalibangan
- Surkotada
- Kunal
- Nagwada
- Banawali
- Rojdi
- Daimabad Bronzes

Mohenjodaro

It was E. Mackay who had described the metal artefacts in John Marshall's report on Mohenjodaro, as also in his own report on Mohenjodaro. The scientific analyses were done by Muhammad Sana Ullah (for illustrations and detailed descriptions see Marshall 1931: 481-508; Mackay 1937-38: 441 ff. Plate nos. refer to these original reports). Earlier I had given a general summary of the Harappan tool repertoire (Agrawal 1971). Recently Chakrabarti & Lahiri (1996) have come out with a more detailed description of the earlier finds at Mohenjodaro and Harappa, Chanhudaro and Lothal which we have followed below. Recent data follow the reports based on earlier excavations. Following the original older descriptions, we have retained the measurements in inches (for conversion: 1 inch=2.5 cm).

Vessels: Many copper vessels were raised from single sheets of metal by hammering. In some cases, they were made in two parts and joined with a "rib being caused by the projecting of the jar". In addition, bases were frequently "lapped on" to the upper parts. There are cases in which the vertical knob handles of lids were secured to the cover both by a rivet and "by pouring molten metal around the base of the rivet for additional security". The heavy bronze vessels were probably cast, although some bronze vessels could also be raised from sheet metal by hammering aided by frequent annealing. In some cases the final finish could be given by carefully rubbing down the objects or by turning them up on a lathe. In such cases, the lathe marks "could have mostly removed by subsequent honing and polishing". The vessels have mostly flat or semi-flat bases, those with rounded bottoms being kept on separate ring-stands. No effort was generally done to strengthen the rims "by turning the metal down a little all the way round". but the common process of flaring the rim partly added to its stiffness. Plate CXL (in Marshall 1931) illustrates the outlines of a few representative vessel-shapes.

1. Pl. CXL, 4: bronze—cast—dish and cover—heavy and well finished with a smooth surface—the cover fitted with a slight projection on the inside, made by thinning the edge, to prevent its sliding off—the cover handle a separate piece riveted to the top—dish diameter 6.55

inches; height 0.9 inch—the cover with a slightly larger diameter—the two together 2.6 inches high—4 ft below surface—room 1, house I, trench E(M), DK Area.

2. Pl. CXL, 7: copper—hammer—marks—plain bent—over rim—ht 4 inches—4 ft below surface—room 9, block 12, section C, DK Area.

3. Pl. CXL, 8: bronze—wide—mounted, plain rim—the base heavy compared with the sides—a sunken band (0.8 inch wide and 0.2 inch deep) at the base—ht 4 inches—2 ft 6 inches below surface—trench E, DK Area.

4. Pl. CXL, 9 and 18: copper—vessel and cover—the vessel made from one metal sheet—the ribbing formed from the inside by beating the metal on a round—edged anvil—ht including that of cover 12 inches—4 ft below surface—house I, trench E(M), DK Area.

5. Pl. CXL, 12: bronze—plain flared rim—the lapped on—8 inches high—4 ft below surface, room 1, house I, trench E(M), DK Area.

6. Pl. CXL, 13: bronze—cast—very thick metal—diameter 12.75 inches, ht 4.4 inches—rounded base—5 ft below surface—room 12, section C, DK Area.

7. Pl. CXL, 14: copper—plain rim 4.6 inches across—9 inches high—2 ft below surface—room 14, block 8, Section C, DK Area.

8. Pl. CXL, 16: bronze—3.05 inches high flask—cast—very thick, solid metal—2 ft 6 inches below surface, chamber 6, house II, trench E(M) DK Area.

9. Pl. CXL, 20: bronze—small, flat base lapped on—0.18 inch thick plain edge—ht 10.5 inches—5 ft below surface—room 9, block 12, section C, DK Area.

10. Pl. CXL, 5: stem and base of a censer—pan missing—copper axe decorated with a fluted pattern, the flutings being hollow on the inside—slightly bent over rim with a raw edge carrying three rows of indented markings—the stem horizontally and regularly fluted by hammerwork and made from a single piece of metal with the base—the knob at the top of the stem of bronze—in solid casting and very heavy—a final finish on a lathe—estimated height 6.65 inches—diameter of base 6.75 inches—room 1, house I, trench E, DK Area.

Blade-axe (Fig. 5.16): The general slope of the cutting edge is on both sides, except in one case where there is a 'true chisel-edge', the slope being only on one side. Mackay takes care to point out that there is 'no skimping of metal' in the manufacture of this tool-type which was first cast in open moulds and then hammered for the requisite hardness. The greatest thickness of these implements is about 'two-thirds down them, which gave weight at that part of the blade where it was most needed'. The specimens were carefully rubbed down after they were hammered because hammer marks survive only in one. The hammering was light in the centre, getting more pronounced at the edges.

Long and narrow sub-type

11. Pl. CXXXVIII, 1: copper—8.9 inches, 0.24 inch thick—cutting edge 2.3 inches wide and rounded—5 ft below surface—room 11, house XXX, block 5, VS Area.

12. Pl. CXXXVIII, 7: copper—4.82 inches long, 0.2 inch thick—sides and butt cut square—unusual in the sense that the 1.32 inches wide butt end is wider than the cutting edge—6 ft below surface—room 87, house IX, block 2, HR Area.

Short and broad sub-type

13. Pl. CXXXVIII, 2: copper—8.25 inches long, 0.35 inch thick—rounded cutting edge

sharply sloped on both sides—butt end with a blunt edge—5 ft below surface—room 11, house XXX, block 5, VS Area.

14. Pl. CXXXVIII, 6: copper—6.25 inches long, 0.3 inch thick—rounded cutting edge sharply sloped on both sides—butt end with a blunt edge—5 ft below surface—room 11, house XXX, block 5, VS Area.

Spear/lance-bead (Fig. 5.24): The width and the thinness of these blades drew comments from Mackay (Marshall 1931) who pointed out that unless strengthened along their edges, they would have been totally ineffective as weapons. He also discounted the possibility of their being knives of some sort because of the total absence of rivet-holes by which they could be “trophy captured from a people of inferior civilization”. However, he suggested that the specimens of this type could be shafted to bamboo shafts and cemented by a resinous substance like shellac. The objects were made from rods of metals which were “little thicker than the tangs”. There was never any attempt to turn out a mid-rib, and their edges were possibly sharpened by hones.

15. Pl. CXXV, 2: copper—9.1 inches long, breadth, 4.1 inches, thickness 0.15 inch near the tang—2 ft below surface—room 14, block 8, Section C, DK Area.

16. Pl. CXXXV, 8: copper—a very fine specimen—length 11.3 inches, breadth 3.5 inches, thickness 0.15 inch—most of it 0.11 inch thick, “very thin, and likely on this account to have been easily bent”—10 ft below surface in the Great Bath area in a street.

Arrow-head (Fig. 5.23): The most interesting aspect of these arrow-heads is that their lithic prototypes are not available.

17. Pl. CXLIII, 12: 1.33 inches long, 0.5 inch thick—evidently cut from a piece of sheet proper—5 ft below surface—Stupa section.

Knife/dagger: Mackay (Marshall 1931: 500) commented on “the smallness of the number of knives and daggers found at Mohenjodaro”.

18. Pl. CXXXV, 3: copper knife—6.7 inches long by 1.23 inches wide—the back thick near the tang (9.17 inch thick) and fine down towards tip to blade—edge sharp and graduated—7 ft 6 inches below surface—Structure V, block 2, Section B, HR Area.

19. Pl. CXXXV, 6: copper—possibly a leather-cutter, since its tip is curved—restored from a perfect example from Harappa—present length 6.2 inches, estimated width 2.1 inches—0.1 inch thick—flat tang—edged only on the convex side—3 ft 5 inches below surface—First Street, HR Area.

Razor (Fig. 5.23): the type is not very clearly determined but Mackay suggests the prevalence of two types.

Razors were classified into double-blade, L-shaped, hook-shaped and simple-bladed sub-types. The double-blade type was most common. “The blades are always very thin and paper-like, and the tangs which are oval in section are not very much thicker. It will be noticed that the two blades of a razor are not the same shapes; probably each side had its own purpose. They were roughly cut out of sheet metal and the blades subsequently spread by means of a hammer before being finally trimmed into shape. None of these razors is very large, the biggest that we have found being only 2 inches across the blade. It seems unlikely that they were set in handles, for in the better preserved specimens the metal tang, thin as it is, would suffice for holding blades as light as these” (Mackay 1937-38: 468).

20. Pl. CXXXVIII, 11: bronze(?)—2.2 inches long, 1.05 inches wide—fine curved edge—2 holes at the back for riveting it to a handle—5 ft below surface—House 17, VS Area.

21. Pl. CXXXVIII, 12: bronze—badly broken—measuring at present 2.28 inches across sharp curved edge—average thickness of the blade 0.9 inch—rectangular tang—6 ft below surface—Room 104, Block 8, L Area.

Saw: in 1931, Mackay (Marshall 1931: 500-501) illustrated only two examples:

22. Pl. CXXXVIII, 8: bronze—"is of much the same shape as the iron saws used of the present day to cut up shell"—18.3 inches long. 6.3 inches wide—thickness corroded—2 holes in the tang for riveting—the teeth well preserved at its tip—5 ft below surface—Room 9, Block 12, Section C, DK Area.

The second example by Mackay in this context is more or less guesswork.

Sickle-shaped blade: Only one example has been cited by Mackay (Marshall 1931: 501).

23. Pl. CXLIII, 25: bronze—1.95 inches long, the maximum diameter of the shank 0.12 inch—the end of the shank bent over to form an eye—3 ft below surface—house 9, block 2, Section 8, HR Area.

Fish-hook: fish-hooks are said to be common at Mohenjodaro.

24. Pl. CXLIII, 25: bronze—1.95 inches long, the maximum diameter of the shank 0.12 inch—the end of the shank bent over to form an eye—3 ft below surface—house 9, block 2, Section B, HR Area.

Chisel (Fig. 5.24): There are 3 types of chisels: rectangular/square in section with uniform dimensions along the entire length, rectangular/square in section with flattened tang, and round in section. The third type is said to be very rare. All chisels are double-sloped. The flattened shanks are expressly meant to be fixed in handles. The pointed chisels with round sections were means for cutting stone. None these chisels are suitable for deep mortise cutting, for their splayed edges would prevent easy withdrawal from the hole. Certainly none of them show evidence of having been used on hard materials. They were probably employed for simple woodworking, and it may be for soft stones, such as steatite, which was very commonly used at Mohenjodaro. The smaller tools were perhaps employed for engraving..". (Marshall 1931: 502)

25. Pl. CXXXV, 11: copper—9 inches long, splayed edge 0.64 inch wide abruptly sloped on both sides—made from a rectangular rod measuring 0.5 inch wide by 0.38 inch thick—tapers slightly towards the butt and the edge 11 ft below surface, Block 4, Southern Buildings Section.

26. Pl. CXXXV, 12: copper—8.2 inches long, made from a square rod (0.4 inch square)—the shank measures 0.7 inch by 0.16 inch and is cut square at the butt—6 ft below surface—room 8, house 8, block 2, HR Area.

Awl and Reamer: One example has been cited.

27. Pl. CXXXV, 7: copper—7.7 inches long, made from a rod 0.28 inch square in section—towards the end it fines down to a point—the shank hammered flat and measures 0.37 inch by 0.1 inch at the butt—the point bent—"from the sharpness of its angles it seems likely that this tool was used as a reamer"—4 ft below surface—First Street, HR Area.

Among the other tool-types, Mackay first mentions needles of which three examples have

been illustrated by him (Marshall 1931: Pls. CXXXII and CXLIII). He then covers kohl-stick ("their blunt ends preclude their being awls, and the fact that the ends are usually carefully rounded and polished proves that they are not pieces of unused metal"), finger-ring (a typical example: internal diameter 0.72 inch, made of wire, 0.13 inch in diameter, with the ends closely touching), earring and bracelet/bangle (a typical example): 2.55 inches outside diameter, 0.3 inch diameter of the round section—tapering points coming close).

In the category of miscellaneous objects are included jar-handle, piping (Pl. CXLIV, 1- cast, 22.5 inches long, 0.78 inch diameter, 0.11 inch thick), shield-boss (Pl. CXLIV, 3- irregular circular piece, 3.3 inches in diameter- marks of 10 rivets around the bevelled edge- certainly patch of some kind), bull (Pl. CXLIV, 2), bird, tube, terminals, spacer, bead, casting, chain and the famous dancing figure of a girl.

In 1938 more data were published on the copper-bronze objects from Mohenjodaro (Mackay 1937-38: chapters 13 and 14). Mackay begins by saying that no distinction can be established between types and shapes on the basis of stratigraphy. He (Mackay 1937-38: 441) also emphasises that "Bronze was known too and used by the people of the earlier occupations as well as later. For instance, bronze containing no less than 22.2 per cent of tin was found at level 30.4 ft below datum and another piece with 8.3 per cent of tin at 33.4 ft below datum". He further points out that in some cases copper objects were wrapped in cotton cloth. A good number of objects in the upper levels of the site came from three hoards. Hoard 1 (room 19, house II, block 14, DK Area), found 4.8 ft below surface (Late I date, according to Mackay), comprised no less than 40 objects including bronze figure of a goat. Hoard 2 (room 28, house VI, block 15, DK Area) occurred 5.7 ft below surface and belonged to Late Ib period. Hoard 3 was found in the same room as Hoard 2 but at a lower depth 7.1 ft below surface. These three hoards were found in 1930-31 but in 1929 another hoard of metal objects had been found. This hoard (room 15 of block 12A of the DK Area) occurred 24.4 ft below surface and thus belonged to a much earlier level. As far as the metal utensils are concerned Mackay (1938: 445) tries to establish some parallels between pottery vessels and metal vessels. Both pans and dishes were found earlier, but frying pan with a simple tubular handle seems to be a new type of utensil.

28. Pl. CXXII, 10: copper- 5.7 inches long with a handle which is a broad strip of metal bent round to form a hollow tube which tapers to an end- possibly inserted into a wooden handle - sides of the pan 0.45 inch high- hammer-marks visible.

Mackay (1938: 450-53) refers to the occurrence of "quite a number of ingots and castings which throw considerable light on the methods adopted by the metallurgists of Mohenjodaro". The plano-convex shape of the ingots (cf. 3.62 inches in diameter, 1 inch thick, base rounded and fairly smooth, the top uneven with characteristic puckering due to the contraction of metal when cooling; p.451) suggests that "the ore was smelted in an open hearth with charcoal over a cavity in the ground into which the metal ran". As an example of casting Mackay (1938:452) refers to an irregular piece which "seems from its appearance definitely to have been broken from a larger mass of metal, for its longer edge shows a preliminary saw-cut, 0.13 inch deep, after which the piece was snapped off". He also illustrates castings of blade-axes which "were so faulty and full of blow holes as to be unusable except for re-melting". These blade-axes were cast in closed moulds set on edge or on one end. However, in this context Mackay (1938: 457-58) draws attention to an axe-adze (Pl. CXXII, 12), found in the Stupa section (open space between Blocks 7 and 10 where there was substantial brick-robbing), 6 ft below surface. He is disinclined

"to accept it as being a product of the Indus valley Culture as we know it". In fact, he "would prefer to regard it as of later date, perhaps even as late as the Kushan Period, despite its being found 6 ft below datum". The axe-adze is 10.15 inches long and made of cast bronze. Although Mackay doubts the authenticity of this particular find, he points out that "the Indus valley people knew of socketed tools, even if they themselves did not use them".

The spear lance-heads and arrow-heads conformed to the earlier types. One of these specimens was found to have two holes through which the wooden mid-rib could be tied by a wire. The distinction between knives and daggers is made by Mackay in the following fashion: whereas knives were meant primarily for cutting or severing something, the daggers were intended basically in the shape of the blade: (1) broad, leaf-shaped; (2) leaf-shaped with curved tips; (3) narrow and straight; (4) triangular with upturned points; (5) broad, curved; (6) narrow curved-edged; (7) hollow-backed; and (8) double-curved. There is a type which is called 'both knife and dagger'. Finally there is an exclusive class of daggers, with two of them having a definite mid-rib.

Sword or dirk: This type was obtained for the first time in the 1930-31 excavations and is double-edged, heavy for their size and well-made and shaped.

29. Pl. CXIII, 3: copper- the blade and tang 15.75 inches long and the greatest thickness 0.4 inch—two rivet holes at the junction of the tang and the blade—in section the blade diamond-shaped—the rectangular tang 0.65 inch wide by 0.28 inch at its thickest part—room 19, house III, block 14, DK Area- Late 1b period.

Saw & Bolts and other objects: A good specimen of saw has been illustrated (Pl. CXVL, 5). It has irregular teeth 'in much the same way as the teeth of the modern saw'. The specimen was riveted to a handle. Among the other types are mentioned sickle, fish-hook, plain hook, chisel, awl and reamer, drill, kohl-stick, needle, bolt, plumb-bob, scale-pan and beam, mirror and spatula, besides some miscellaneous objects. The new types here are plain hook, drill, plumb-bob, scale-pan and beam, mirror and spatula. Interestingly, a bronze hook (Pl. CXXIV, 32) was initially thought to be elephant-goad, although Mackay (1938: 472) writes: "I am now assured that it is much too small to have been used for that purpose, though when perfect it may have been very similar in shape to the goads in use in India at the present day". Drill (Pl. CXXXI, 6) represents a type of small pointed implement. A bolt has been illustrated in Pl. CXXXVII, 14, "It is 25.15 inches long, and tapers slightly to a blunt point 0.59 inches wide by 0.37 inches thick. The head is slightly bent and measures 0.98 x 0.92 inches. This bolt appears to have been smoothed in any way" (Mackay 1937-38: 476). Plumb-bob (Pl. CXXV, 50) is a round lead ball, 1.2 inches in diameter, with a copper or bronze staple attached. According to Mackay (1938: 476) this is 'undoubtedly a plumb-bob'. Scale-pan and beam (Pl. CXIV, 10 and Pl. CXXXII, 7) are basically a flat-edged dish 'turned into a scale-pan by boring three small holes at regular distances in its rim' (diameter in one case 3.26 inches). The beam is identified by its association with two scale-pans (6.2 inches long beam in one case). Mirror (Pl. CXIV, 1) "is bronze, slightly oval, and with the edge of the face raised 0.17 inch. The back which is quite plain is somewhat irregular. The polish has completely disappeared from the recessed face of the mirror. The handle is rectangular in section with a hole at the end, and it looks as if there had been another hole close to the mirror itself, but, if so, it has been filled up by corrosion.... The recessing of the faces of all these mirrors was perhaps intended to protect them and to preserve their polish. It is almost certain that the handles were at one time encased with wood and therefore longer

than they now are, for these mirrors are very heavy and difficult to hold in their present condition. The slightly pear-shaped form of all three is in noticeable contrast with the round or elliptical mirrors of early Egypt, Sumer and Elam.... Metal mirrors are still in use in India today; certain orthodox Hindus prefer them to glass mirrors for their religious ceremonies" (Mackay 1937-38: 478). Spatula (Pl. CXXXIII, 18) has a very thin blade (0.04 inch thick) and was perhaps used to remove paint or cosmetics from a palette. On the use of copper or bronze in personal ornaments, Mackay (1938:501) writes the following: "Copper and bronze were frequently used in the manufacture of beads, spacers and terminals. The two latter were always made of thin metal, but the beads which are generally short-barrel shaped or globular are solid castings, the holes through them, it would seem, being drilled later, though it is possible that they were cast with holes which had to be improved. Traces of gold survive on one copper, or perhaps bronze, bead, and it is possible that many of these beads were so finished to imitate gold". Among the terminals the most common shapes is the triangular one.

Harappa

The following summary of the copper artefacts found in the earlier excavations at Harappa is based on Chakrabarti & Lahiri (1996) and Vats (1940). All references to plates belong to Vats (1940).

The most important find was the jar no. 277 (IIIrd Stratum, Square M11/15, Mound F) which contained the following artefacts (Vats 1940): 13 blade-axes, 8 narrow and long axes, 2 double-axes, 11 daggers with tapering sides and with or without curved tips, 1 mace-head, 13 spearheads and flaying knives, 1 lance-head, 1 arrow-head, 1 chopper, 2 saws, 10 chisels with or without shanks, 2 cast-bars for making chisels, 1 flat strip of metal, 1 stylus, 1 beam of a weighing scale, 1 semi-oval, hollow terminal, 5 solid bangles, 1 rod for making a bangle, 3 hollow bangles, 4 flattened leaves for making hollow bangle, 4 thick rectangular copper-pieces, 1 thin bowl with tapering sides, 2 large folded sheets of copper, 2 thick broken pieces bearing prominent hammer marks, several more thick pieces and 1 small lump of lollingite.

The broad types of objects found at the site are the following: Vessel, adze (one socketed), dagger-knife, spearhead, chisel, sickle, scraper, razor, gouge, nail-parer, surgical or toilet set, cobbler's awl (?), needle, pin, antimony rod, mirror, fish-hook, arrow-head, hasp or a typical Indian kundi made of a round copper bar, hook, and latch (?). Among the vessels, Vats illustrates a carinated jar from Mound AB, Pit II, Stratum II, Pl. CXXII, 24-height without cover 7.8 inches, diameter at the mouth 7.7 inches and across the body 11.5 inches which is made in two parts, the upper part being lapped on to the lower one by hammering the two together. Owing to lathing, the joint is imperceptible. There is nothing special about the adzes from the site except the lower part of a socketed specimen (Pl. CXXII, 18). Among what Vats calls 'dagger-knives' there is a specimen with a long, narrow and curved tip with double edge and incipient, vertical mid-rib down the centre. This has two rivet holes and the shape is considered 'unique at Harappa and Mohenjodaro'. Similarly, among the spearheads which are relatively common and of various shapes, 'often with long tangs which are sometimes holed for rivets', there is a specimen (Pl. CXXIV, 49) which is unique in having a strengthening mid-rib, with two holes at the base of the head and a third one at the base of the tang. Three chisel-types are noticed: a long and narrow type with flattened shank and splayed edge; a short, thick and strong type with splayed edge and burred butt, and tanged chisels, the last type being rare and reported for the first time from Harappa. A number of straight edged and curved knives and curved sickle blades have

been documented, along with 'scrapers' (flattened, with rounded edge, length 3-4 inches). Razors are Mohenjodaro-type. The cutting edge of gouges are circular or approximately so. The nail-parer illustrated in Pl. CXXII, 14 is said to be 'exactly similar to those now used in the Punjab.' What has been called a 'surgical or toilet set' (Pl. CXXV, 1) is a bunch of three bronze instruments (roughly 4-5.3 inches long) held together by their looped and interlaced ends. One is a double-edged knife; the second is a pair of pincers, and the third one is a piercing rod. Among the other varieties of artefacts (cobbler's awl, needle, antimony rod, mirror, fish-hook, arrow-head, hasp and latch) the interesting ones include a hasp or Indian kundi made of a round bar (0.35 inch in diameter) and latch (CXXII, 28 and 33). These are strong objects of cast bronze (3.75 inches long and 1.37 inches broad in one case, and 2.37 inches long and 1 inch broad in another).

Lothal

According to S.R. Rao, the excavator of Lothal, personal ornaments form the bulk of the copper and bronze objects from Lothal. The total number of artefacts recovered is about 1,500, out of which the shape and use of about 1,000 could be recovered (Rao 1985: 520). Among the axe-types at Lothal, the first type consists of a flat axe with a long narrow blade or a broad one ('blade-axe' of two types in the earlier site reports). The second type has a thick triangular section and can be grouped with the socketed axe specimens from elsewhere. In fact, one of the three specimens of this type found at Lothal appears to have had a shaft-hole. The new type is a single specimen of what is called a 'crescentic sleeved axe' (Rao 1985: figure 107—phase IV, Period A, axe with 2 unsymmetrical sleeves on the margin—one edge blunt and crescentic—the opposite edge and sleeves damaged—deep hammer marks all over the surface). Spearheads conform to the usual type from other sites: leaf shaped blades with a tang and ending in a point; some have one or two holes in the centre of the tang or blade for fastening them to a shaft. Specimens of digger range in length from 1-2 inches to 3-4 inches. One of them has a folded socket while another has a rivet-hole near the tang. Arrow-heads are 0.75 to 1 inch long. Razors have curved, triangular and L-shaped blades. Chisels are common and have 3 categories: square/rectangular section and with parallel margins; blade square/rectangular in section with flat tangs; and blade with round section. A small wedge-like chisel with a triangular section is called a unique find at Lothal. A drill-bit at Lothal "has twisted grooves with a chisel end and works exactly like a modern auger. It must have been fitted into a T-shaped frame to bore holes by rotary movement with downward pressure" (Rao 1985: 532). Awls and needles are of three types: the first has a pierced eyelet at the sharpened end and was possibly used for stitching tougher material like leather and flax; the second type has a thicker end and no eyelet hole, the third type has a sharp tip. A partly damaged saw with a curved blade and three teeth intact has been reported from Lothal and it is distinctive in the sense that it has a straight serrated edge and "must have been used for cutting grooves in ivory and shell objects of circular shape, *e.g.* gamesmen, rings, etc. or for trephining" (Rao 1985: 533). In view of the large size of some of the fish-hooks (barbed and non-barbed) it has been presumed that 'sea-fishing was well known to the Lothal fisherman'. Nails occurred with or without a head and some rods have been found to have longitudinal grooves at regular intervals. A completely new type at Lothal is a single specimen of 'plainer-bit' (figure 112, 5 in Rao 1985): rectangular with a small concavity on either margin—thick butt and working edge sloped from both sides. Among the personal ornaments occurred bangles (one type cast in a mould and with a corrugated edge—average internal diameter 2 inches), rings (both coiled and plain), ear-ornaments (rings and

pendants) and beads (including spacer beads and faceted beads). Animal figurines comprised a couchant bull, hare, dog, bird, fowl, etc. Chain-links, spoons, a mirror and a carinated jar have also been reported from Lothal.

For the evidence of local melting among the crucible and moulds from this site, Rao (1985: 557) mentions a small sandstone bowl-shaped crucible used presumably for melting metals and two rectangular slabs of sandstone with groove-like depressions used for casting pins and needles. Three areas seem to be connected with copper crafting/smelting (Rao 1985: 522). Five rectangular sink-like brick pavements have been interpreted as a coppersmith's workshop. That they were used by metal craftspersons is suggested by the presence of a pot furnace containing ash near each sink as also bits of muffles. The other relevant finds in this area are two terracotta crucibles, small lumps of copper and the crescentic sleeved axe mentioned earlier. A circular kiln of mud bricks (6 ft in diameter and 2 ft 3 inches deep) is located near the workshop and was possibly used, according to Rao, for the remelting of the ingots. The relevant finds here are an earthenware bowl and large copper sheets, recovered in the form of flattish chunks. A rectangular furnace of burnt bricks was found in a room of a mud-brick structure (151 in street 1 of the Lower Town). The contents of the kiln were ash and fragments of terracotta crucible while a cubical stone anvil with signs of use was *in situ* near the kiln. The presence here of a stone mould for casting pins and awls, a copper pin, a broken copper chisel and a hammerstone with a socket for hafting also suggests copper/bronze manufacture.

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Banawali

The pre-Mature Harappan phase at Banawali, we have already discussed in chapter 4. To the excavator (Bisht 1993: 113-24), the advent of the Mature Harappan (Period II) at the site appears a bit abrupt. He says, "With proverbial dramatic precocity the full-bloomed Indus culture makes its appearance at Banawali. This includes its essential culture appurtenances: town-planning and architecture, ceramics, seals, script, weights, clay figurines, terracotta 'cakes', items of ornament and miscellaneous knick-knacks and tools. The older ceramic tradition continues throughout Period II as a culture-companion of the new pottery corpus but in reduced frequency. Among the tools, there are objects of copper: arrow-head, spearheads, a fragmentary sickle blade, the typical razor, chisels, rings, double spiralled and simple pins, ear/nose rings and fish hooks. There are points, a knife and scrapers of bone. Chert blades and fluted cores and flakes are also present. Other objects include clay net-sinkers, balls, pallets, sling balls, longish cones and solid wheels made of clay, besides numerous other household implements".

Chanhudaro (Fig. 5.17) (All plates refer to Mackay 1943)

It is interesting to note that Marshall thought of the Indus civilisation as indigenous but Mackay traced it to West Asia and Iran (Mackay 1943: 175). As most of the copper and bronze artefacts found at Chanhudaro came from Squares 8B, 8C and 9C, Mackay thought that this was 'the quarter of city inhabited by the metal workers'.

Utensils: A copper canister (Pl. LXXIII, 37 - all plate nos. in this description refer to as given in Mackay 1943) fitted with wire loop handles. It may be noted that handled *vessels* are a rarity in the Indus corpus, except for the handled pans, of which some examples have been found at Chanhudaro. Another remarkable find is that of a fluted cosmetic jar (Pl. LXXIII, 39), with a very narrow (0.22 inch diameter) mouth and a long neck, like those used for keeping kohl.

The fluting ornamentation is unique among the Harappan *vessels*.

Other finds: Jar covers, scale-pans and beams, blade-axes, adzes, saws, spearheads, daggers, large and small knives, razors, arrow-heads, chisels, fish-hooks, awls, rods, tubular drills, ingots and plumb-bobs are similar to those found at Mohenjodaro and Harappa. The scale-beams have slightly thickened ends to prevent the strings holding the pans from slipping off. The blade-axes are both long and short, and inscribed in some cases. The adzes are longer and slender than axes. Only one specimen of saw was reported. Some agate nodules for making beads have saw-marks. There are two new types in razors: U-shaped and crescent-shaped. Two examples of ranged arrow-heads (Pl. LXXIII, 1 and 13) have been found at Chanhudaro, but otherwise the arrow-heads belong to the usual type. Mackay (1943: 183) mentions that 'they have all been cut from thin pieces of sheet copper, varying from 0.02 to 0.05 inches in thickness, and must have been set in the tapered and slit ends of their shafts, so that the latter formed a stiff wooden mid-rib. A cement of some kind must have been used to fix these heads in place, for no tie-holes in them occur. Both fish-hooks and chisels (5 varieties: uniformly thick tang, flattened tang, round in section, short and round/rectangular/square in section, and short and pointed) conform to the Mohenjodaro specimens as do awls, rods, plumb bobs, tubular drills and ingots. 'Bead-tools' of Chanhudaro (Pl. LXXX, 1-8) constitute a new type (cf. one specimen: bronze casting-1.9 inches long, with a point protruding from its lower end- this point is shielded by a flang partly encircling it). These were used in the production of minute steatite beads. The shovel (Pl. LXXIV, 13) is a new type. Stave heads (Pl. LXVIII, 4, 5, 7) might have served to surmount ceremonial staffs. There is also a specimen of spatula (Pl. LXVII, 8).

The evidence of local manufacture: Unfinished castings were noted in three of the hoards discovered at Chanhudaro (Mackay 1943: 40-41). One hoard of 16 objects was found buried at locus 284, in the remnants of the room of a house in Square 8/B; although the excavator noted "several unfinished castings", these castings are not mentioned in the catalogue of illustrated objects (Mackay 1943: 300). Another such hoard which contained a casting (for the production of a knife?) was found north-east of pavement at locus 212, Square 9/C. In the largest deposit consisting of 37 pieces at Square 8/C, locus 297, the unfinished casting was presumably intended for the manufacture of an implement. In this hoard, a bronze rod, round in section and about 13.75 inches in length has been characterised as an ingot (Mackay 1943: 187). Mackay (1938: 188) also noted the concentration of artefacts in a particular sector as denoting the metalworkers' area. However, no furnaces or kilns that could have been used in the production process were discovered, and consequently it has generally been argued that the rough work was carried on outside the city and brought in only for the process of finishing.

Heidi Miller (1998) has done a very promising systematic study of the metal artefacts from Chanhudaro. In her analysis, she explains, "Labels such as adze, axe, spear or lancehead have not been used because these terms carry a functional interpretation based on a genetic shape shared with more modern examples, and as descriptive terms, are not well defined. Instead, a systematic classification for tools has been devised that groups tools with similar working edges with each other. The purpose of this is to move beyond the automatic assumption of function to explore the varied ways different tool shapes and sizes (i.e. types and subtypes) could have been used".

Heidi Miller (1998) explains her typological criteria: "Four attributes are used to define tool types: overall shape and size of the object, shape of the working edge, and whether part

of the tool may have been hafted. To begin with, the shape of a tool is classified as either a blade or a rod. A blade is flat and rectilinear in section, and the size difference between the width and the thickness of the body of the tool is greater than 1 cm; that is, the object is much wider than it is thick. The width and thickness of rods are similar and the difference between the two measurements is less than or equal to 1 cm. Rods may be round or rectilinear in section. The distinction between blades and rods reflects the different size of the working edge than rods. Consequently, the two shapes may have been used for different types of tasks.

"Along with the overall shape and size of the tool, the shape of the working edge is the third attribute considered in determining tool types. The two main edge forms are: wedge, also referred to as a chisel edge, and is found both straight and flared; and points which can be either dull and round, or sharp and pointed. The fourth new attribute considered is whether the tools could have been hafted or not, and if so, how. These four attributes, the overall shape of the objects, its overall size, the size and shape of the working end, and how it may have been hafted, are what determine tool type. Types 1 through 8 are blade tools, where working edges are wide areas, and types 9 through 13 are rod tools with smaller, shorter and more concentrated functioning ends. Types 14 and 15 are unique tool types. All sizes listed below refer to objects in the Chanhudaro collection only". (Heidi Miller 1998 - I have used her full name to distinguish her from Heather Miller!)

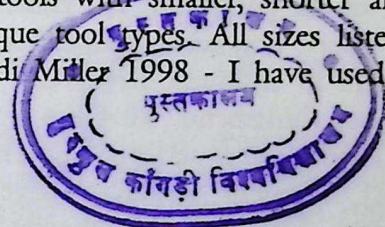
Characteristics of the Chanhudaro metal assemblage

Heidi Miller has studied 521 objects from Chanhudaro, out of which 64% are tools, 26% are ornaments, 7% are *vessels*, and 3% are miscellaneous objects. She hopes that in the future it will be interesting to see if this same broad functional pattern is represented in the assemblages of metal objects from other sites in the Indus valley, and how this pattern may vary through time and space.

Within each category, she distinguishes certain patterns. For example, out of 37 copper *vessels* found at Chanhudaro, 27 (or almost 73%) were dishes. In the tool category, rod shaped tools make up 52.1% of the sample while blade tools are 47.9%, showing a relatively even distribution between the two shapes. There are 334 metal artefacts classified into 15 tool types and no single type makes up more than 17.2% of the category. There appears to be a range of tool types with no dominating specific type, suggesting that copper alloy tools were used for a variety of purposes. Only three copper objects from Chanhudaro are inscribed: type 14, described by Yule as a 'snarling iron', and two examples of tool type 3A blades.

She explains that this is a functional typology for metal objects. It begins with four categories which reflect general patterns of use: *vessels*, ornaments, tools and miscellaneous objects. Each category consists of specific types defined by shape, size, and if a tool, by the working edge and hafted area. "Definitions have been made as clear as possible and it is hoped that future research will further clarify and expand upon the types presented here".

She hopes that this typological tool will allow for comparative studies between sites as well as an examination of spatial patterning of types within a site, and will facilitate comparative studies between the ongoing research into the technological aspects of metal craft production, and together, the typological and the technological, will provide a clearer picture of how metal objects were made and used in the Indus valley (Heidi Miller 1998).



Rojdi

From Rojdi, a Harappan site from Gujarat, Chitalwala (1989:157-97) reports that no analysis has yet been done on the rich inventory of copper-based metal implements from renewed excavation at Rojdi. These artefacts are important since they document the abundant presence of metal tools within the post-urban, Rojdi C, context within Saurashtra. The axe, bar, celt, parasu and bangles are especially important in this regard. He gives the following inventory of artefacts.

Copper Axe, 14.8 x 9.5 x 0.6 cm. Found in the Large Building, Main Mound. Trench 46L. Rojdi C.

Copper Bar Celt. 32.1 x 4.8 x 0.7 cm. Found in the Large Building on the Main Mound. This object was broken in antiquity when it was bent as it was placed in a shallow pit. Trench 46L. Rojdi C.

Copper *parasu* or *knife*. 17.5 x 5 x 0.3 cm. This cutting tool has parallels in the Sorath Harappan context at Mitathal (Suraj Bhan 1975: 65) and Kurada in Rajasthan (Agrawala 1980: PI II, p. 90). Found in trench 75L on the South Extension. There are no building associations. One side of the parasu has an "endless knot" design on it (see also Marshall 1931, Pl. CXVIII, 5). The upper, non-cutting edge, has transverse marks which appear to indicate that blows were struck there in antiquity, Rojdi C.

Copper Ornaments. 10.4 x 4.6 x 0.1 cm. This ribbed object was fashioned on a sheet of copper. There are no perforations. The object has no parallels that we know of and it has been called an "ornament" simply to give it a name. Found in trench 76L Rojdi C.

Copper Bangle. Approximately 17.5 cm diameter, overlapping ends. Trench 77I, South Extension, Rojdi C.

Copper Toe Ring. Approximately 3 cm diameter. From trench 75I, South Extension, Rojdi C.

Copper Ring. Approximately 2.5 cm diameter. From trench 75L, South Extension, Rojdi C.

Copper Bangle. Approximately 4.5 cm diameter. From trench 27S, North Slope. Rojdi C(?).

Copper Ring. Approximately 2.1 cm diameter. From trench 20P Rojdi B.(?)

Copper Pin. 9.6 cm long, approximately 0.3 cm diameter wire. From trench 76J, Rojdi C.

Padri

From this Harappan site in Gujarat, Shinde and Elizabeth (1993: 145-247; Fig.1) report a unique type of fish-hook. "From the surface of the floor of structure 12 was recovered a unique copper fish-hook, which is 14 cm long, with a barbed point and a loop on the other end. It weighs 45 gm and is in a very good state of preservation. It is round in section. The loop on the other end of the fish-hook does not touch the shaft. Such a large fish-hook would probably be used to catch large marine fish, weighing more than 50 kg, which leads us to believe that the Harappans of Padri had mastered the technique of deep sea fishing.... The Indus valley fish-hooks are similar to modern ones and this feature is suggestive of a continuity of this culture-trait. The best metallic fish-hooks were probably developed by the Harappans, and were certainly superior to those from contemporary sites in Egypt and Mesopotamia".

Dholavira

This Harappan site is probably the most impressive in the Indian part of the subcontinent. Site has been discussed in chapter 4. It is a massive site with stone fortification. It has been excavated by Bisht for about a decade. Fig. 5.22 shows a few spacers, rings and bangles. Fig. 5.28 shows some blades, arrow-heads and chisels.

Surkotada

The site in Kutch yielded 129 objects, besides a hoard containing an unspecified number of beads and bangles (J.P. Joshi 1990: 266-74). The main types are: simple blade and crescent-shaped blade, long or short chisel with rectangular-section long and narrow blade, arrow-head, knife with thin leaf-shaped blade, drill, spearhead with a tang, lid with raised edge, socketed axe, fish-hook, antimony rod, bangle, ring, ear-ornament, hook and chain. In addition, fragments of a crucible have been found.

1. Fig. 68, 1- flat axe, rectangular cross-section-sharp crescentic edge-24.3 cm length, 9.3 cm broad and 0.7 cm thick-mid-level of Period IC.
2. Fig. 68, 2-chisel-sharp, double-sloped edge - squarish cross-section-rectangular tang-30.5 cm length, 1.7 cm broad in the lower end and 2.7 cm in the upper-mid-level of IC.
3. Fig. 68, 3-axe fragment, probably socketed-edge 4 cm wide—mid-level of IC. (Fig. 68 in Joshi 1990).

HARAPPAN INSCRIBED METAL OBJECTS

Kenoyer & Miller (1999) have studied the inscribed metal objects too. This section is based on their study.

Although it has not been possible to make an exhaustive study of the types of metal objects on which inscriptions occur, the recent publications of inscribed objects from the Indus valley Tradition sites (Shah and Parpola 1991; Joshi and Parpola 1987; Parpola 1994a and 1994b; Yule 1985a and 1985b) reveal some interesting patterns. Large axes, adzes, spears, chisels and sheets of copper often have one or more signs chiselled into one or both sides. The inscriptions are usually in a vertical line down the centre but in the case of some celts, they are located at the butt edge. In most instances, the script would be obscured by hafting or damaged during use, and this suggests that these metal tools may have had some specific ritual or symbolic function.

One category of metal objects that was used almost exclusively for inscriptions is flat, square to rectangular copper tablets. At Mohenjodaro hundreds of these inscribed tablets have been recovered (Marshall 1931; Mackay 1937-38; Yule 1985a). The inscriptions consist of Indus script and animal motifs, usually on both faces of the tablet. The engraving may have been done with either a stone burin or a bronze graver. So far this type of engraved tablet is unique to Mohenjodaro, but copper tablets with raised script were found at Harappa by Vats (Vats 1940) and also by the Harappa Archaeological Research Project (HARP) (Meadow and Kenoyer 1994). Due to heavy corrosion, the techniques of manufacture have not yet been determined. The script on both types of tablets was not written in reverse and therefore these tablets were not intended to be used as seals, but represent some sort of ritual or economic token (Parpola 1992).

Usually, Harappan phase seals are made from fired steatite, but there are two examples from Mohenjodaro, of silver seals made in the standard square shape with a boss (Mackay 1937-38:348, Pls. XC,1, XCVI, 520). Mackay suggests that they were first cast with the animal motif, script and boss, and later touched up using a graver. The edges have been scraped and pared, but the rest of the surfaces are too corroded to determine the exact nature of manufacture.

Careful examination of some gold ornaments from a jewellery hoard in DK-E area at Mohenjodaro by Kenoyer has revealed the almost invisible traces of inscriptions that have been overlooked by previous scholars. Of particular interest are gold pendants that have often been referred to as "needles" (Marshall 1931:251-53, 521, Pl. CLI, B 3, 4, 5). Two of three pendants

are inscribed. The third pendant is currently on display at the National Museum in Delhi and it has not been examined, but it too may be inscribed. On one pendant the five signs encircle the entire object, while on the second example a sequence of five different signs are inscribed along the length of the pendant. From this same hoard came two pairs of gold caps or terminals that would have been affixed to the ends of beads. One of each pair of gold caps has an identical inscription consisting of a single sign.

All of the inscriptions appear to have been made by the same sharp and very pointed tool, and give the impression of being written in the same "handwriting". These inscriptions are extremely important because they are clearly different from the types of inscriptions found on the large copper celts and chisels. These inscribed gold objects were found inside a copper cooking pot that had been covered by a copperplate. Other items in this hoard include a massive belt made of carnelian and bronze beads, gold ear studs, stone beads and some copper vessels. It is possible that before this wealth was hidden away, the names of specific owners were incised on some of the gold jewellery (Kenoyer, on-going research).

LATE HARAPPAN REPERTOIRE

We have included here sites in Pakistan, Haryana, Punjab, and Maharashtra.

The late Harappan levels are stratigraphically established at many excavated Mature Harappan or Indus civilization sites. The quantity of metal used is now limited and no new tool-type seems to appear.

From Haryana and Punjab Sites

Bara	:	bead, fish-hook
Bhagwanpura	:	rod
Dadheri	:	chisel, hook
Daulatpur	:	bangle, fish
Hulas	:	bangle, chisel, ring and wire
Mitathal II B	:	several pieces of bangle, flat
Raja-Karan-ka-Qila	:	spearhead
Sanghol	:	chisel, celts, 1 <i>parasu</i> (a type of 'double axe')

The Area between Swat and Chitral

Period IV at the site of Ghaligai in the Swat valley has been placed early in the second millennium BC. Metal occurs first in this period, and in addition to Ghaligai, the sites of Loebanr III and Bir-kot-Ghundai deserve some consideration in this context. The bulk of the evidence, however, comes from the succeeding 'Gandhara Grave Culture' complex, the evidence of which occurs widely in the region (Stacul 1987).

From Swat-Chitral Area

Ghaligai	:	spearhead, hook
Loebanr III	:	pin, fish-hook, chisel, wire
Bir-Kot-Ghundai	:	pin, fish-hook, point, wire
Loebanr	:	pin, earring, knife, pendant, buckle, spearhead, bead
Katedai	:	pin, earring, bead, pendant, knife, bodkin/needle, fish-hook, horse figurine

Butkara II	:	pin, knife, buckle, earring, hook
Timargarha	:	pin, toilet object, needle, hairpin, pendant, earring, bangle
Zarif Karuna	:	ring

The major evidence of copper smithy occurs in a pit containing ashes and charcoal and a chisel at Loebanr.

From Protohistoric Kashmir

Burzahom	:	arrow-head
Gufkral	:	hairpin with coiled head

DAIMABAD BRONZES

We discuss below Daimabad copper finds, because the excavators have now changed its affiliation from Chalcolithic to Late Harappan. We will also discuss the big statuary bronzes discovered from the site. About these latter bronzes, we have to be careful. We have to note that: 1. They do not have lead in any significant quantity compared other Harappan artefacts. 2. They show significant presence of As, in contrast to the Chalcolithic artefacts. 3. In typology they are totally different than any objects found in protohistoric India. 4. They are very heavy - some weighing 29 kg! - and so much of precious metal was never used in statuary in the whole of Harappan or Chalcolithic repertoire. Such large scale use of metal on statuary is known in India from Historical period only. Spending so much of metal on non-utilitarian artefacts, goes totally against the grain of the Harappa culture. We know of tiny animal figures and the dancing girl which weigh only a few grams. If we take into account all these facts and also the fact that the discovery is not at all from a controlled excavation but an accidental find, I do not think one can include these finds among the Harappan artefacts. If we compare the Harappan metal repertoire with the Chinese (chapter 10), the stark contrast between the monumentality and elitist nature of the Chinese *vessels* and statuary and the functional and frugal Harappan assemblage become quite manifest. We will discuss these bronzes below with these clear provisos.

Dhavalikar (1993: 421-26) has described the large Daimabad bronze objects as follows: "The chariot and bull are the most remarkable pieces in the hoard. Its total length is 45 centimetre and the width is 16 centimetre. The complete bronze consists of an elaborate chariot yoked to two bulls and driven by a man standing within it. Two solid wheels rest over the light body of the chariot. The wheels have a projecting hub on the inner side in which the axle is fixed so that is moved along with the wheels. This is an extremely interesting feature.

"The elephant is the largest of the three animals in the hoard. The beast stands on a platform 27 centimetres long and 14 centimetres broad. There are four ring loops which once held the wheels, all of which are unfortunately missing. The total height, including the platform, is 25 centimetres. The large trunk is curved at the lower tip but the tusks appear to be broken or not completely indicated. A short tail is almost hidden in the rump. This animal recalls another bronze elephant from the Southeast Deccan (Barret 1958) which is dated to about the third century AD. Barret's specimen is a female, standing, or rather running, on a platform with raised edges and ring loops for wheels (all of which are missing). There is a small bell tied around its body.

"The rhino stands not on a platform as in the case with the elephant, but on two horizontal bars over two sets of wheels; the bars are bent at both the ends with the axle passing through

them. The wheels, which are solid with a projecting hub on the inside, are fixed to the axle and move along with it. The rhino is 25 centimetres between the two sets of wheels. Skin folds on the animals' body are rather stylistically duplicated with those on the back and the belly forming a sort of rectangle.

"The buffalo also is modelled in a naturalistic manner. Its height, including that of the wheels, is 31 centimetres and the length is 25 centimetres. It resembles a bison somewhat, but on close observation it is clearly a water-buffalo with characteristic transverse ribbing on its horns. The animal stands on a platform similar to that of the elephant, but the corner near the right foreleg is broken. The axles attach to the platform through vertical bars which are provided with holes. The front wheels are smaller (eight centimetres in diameter) than those on the rear (10 centimetres)".

Dhavlikar finds it tempting to identify the person in the chariot as "Pasupati, 'The lord of beasts', for the simple reason that all the animals, save the tiger, which appear on the famous Pasupati seal from Mohenjodaro, are present in the Daimabad hoard. Marshall's identification of Pasupati on the seal was based on comparisons with medieval representations of Siva (Marshall 1931: I, 52-56; Pl. VII, 4). Presently, however, one is not concerned with the identification and the iconography of the figure. One can only conclude that the evidence discussed in the foregoing pages amply demonstrates that in all probability the bronzes in the hoard belong to the late Harappan period at Daimabad, and that they were probably imported from Harappa, or some smith from Harappa made them locally".

Table 5.1 Copper objects from Daimabad

PHASE	I	II	III	Overlap	IV	Overlap	V	TOTAL
Objects				III/IV	IV/V			
Bangles	2	x	x	x	2	3	8	15
Chisel	x	x	x	x	1	x	x	1
Celt(frg.)	x	1	x	x	x	x	x	1
Spearhead	x	x	x	x	1	x	x	1
M.goddess	x	x	x	x	x	x	2	2
Rect.piece	x	x	x	x	x	x	1	1
Trap.piece	x	x	1	x	1	x	x	2
Razor	x	x	x	x	1	x	x	1
Wire	x	x	x	1	x	x	1	2
Lump	x	1	x	x	x	x	1	2
Slag	x	1	1	x	x	x	x	2
Total	2	3	2	1	6	3	13	30

Sali excavated Daimabad, in Maharashtra. It yielded an assemblage which has been variously named as Chalcolithic and Late Harappan. It has become more famous because of the massive bronze objects that have been accidentally discovered near the site, though they are no way stratigraphically related to Sali's excavations (Sali 1986; Dhavalikar 1993: 421-26). We will first discuss the excavated remains.

Sali reports, "Most of the specimens were found in a highly corroded state. Specially the two bangles from Phase I were in so advanced a stage that the encrustation in one of them crumbled very fast so much so that within a short period of a couple of years only a thin wire of one of them has survived. The extant wire also, being beyond the scope of chemical treatment, is likely to be completely corroded leaving behind only the powder of encrustation. The other bangle was also heavily encrusted and was broken into pieces as a result of further corrosion. Only those specimens which could withstand chemical treatment were subjected to it and the rest had to be left without cleaning".

SOCIO-ECONOMIC INFERENCES OF THE HARAPPAN METALLURGY

Heather Miller (1998) has drawn the following socio-economic inferences from her detailed pyrotechnic studies.

The fact that the noxious, dangerous firing stages of high-temperature crafts took place in densely populated city centres is counter-intuitive, given the focus of the Indus peoples on civic maintenance and organisation. Is this production taking place within the mounded cities of Harappa and Mohenjodaro because it was controlled by a powerful elite, able to use city space as they wished? Or do these production sites indicate that civic authority was not an absolute power, but that city growth and structure involved compromises between the needs of many different city inhabitants, including craftspeople? Obviously, this opposition—control of production location by a powerful elite civic authority vs. control by compromises between various groups of city inhabitants—forms two ends of a continuum. Various crafts and even various workshops no doubt fall at different points along this continuum of control. But where? This is a field of study still in its formative stages, but a number of suggestive points have been made about social relations relating to craft production within Indus cities.

The kilns from the Berkeley excavations on the north-west corner of Mound ET at Harappa have been interpreted as a potter's workshop located in the same area for several centuries, perhaps a family workshop as no evidence for administrative control was found (Wright 1991). This formed a strong contrast with the perceived 'industrial quarter' from Vats' excavations on Mound F, and with 'bazaar-like' workshops at Mohenjodaro reported by the Aachen-IsMEO project (Pracchia *et al.* 1985: 242; Vidale 1989: 172). Unfortunately, both of these later patterns have been called into question. It is now clear that we have to re-evaluate the assessment of Vats' sixteen kilns so popular in the secondary literature. Rather than an 'industrial quarter', these kilns represent long-term use of this area for smaller-scale pyrotechnological production of unknown goods, probably pottery. Also, the IsMEO researchers have themselves noted regretfully that they were carried away in their initial enthusiasm, and now believe the 'bazaar-like' rows of workshops in fact result from geomorphological, post-depositional groupings of the manufacturing debris (Vidale *in press*).

Miller thinks that it is simply a case of the situation being more complex, and thus requiring more study than originally expected. What then can we say about urban Indus workshops, particularly for high-temperature manufacturing? Miller concludes with some general points about Harappa, relating to the overall site structure, the structure of individual mounds, the distribution of particular crafts, the organization of production areas, and some comparisons with the distribution of craft industries at Mohenjodaro as given below.

Overall Site Structure

Indus sites are usually viewed as very ordered spaces, with a grid plan and elaborate waste and water disposal systems. However, this ordering is not very obvious where manufacturing is concerned. All of the mounds at Harappa (and Mohenjodaro) had high-temperature manufacturing areas. Nor does there seem to be a division in the locations of the production of 'everyday' vs. 'elite' items in relation to particular mounds. Especially at Harappa, there is no apparent 'citadel' mound, or 'high' mound, or 'elite' mound, at least as far as the distribution of manufacturing is concerned. (See also Kenoyer 1997a: 55-56.)

The Structure of Individual Mounds

Nevertheless, there may be some hints of order at Harappa in terms of the general location of manufacture within each mound. It appears that a preponderance of manufacturing of all types took place on the southern half of mounds. If this pattern of manufacturing on the south side of mounds does hold with future research, it cannot be due solely to prevailing wind patterns, given the southern location of lithic working areas (which did not involve firing), but must represent a definite decision on the part of the Indus craftspeople and/or civic planners. In fact, the considerable evidence for pottery production on the north side of Mound ET as well as the kilns on the north-west corner of E, which would seem to provide counter evidence to the southern location of production areas, might in fact represent exceptions due to special attempts to protect from or take advantage of prevailing winds. Unfortunately, the surface survey evidence from Mohenjodaro cannot be applied to this question, as only about a quarter of the site was surveyed, in an unsystematic fashion (Bondioli *et al.* 1984: 18).

The Distribution of Particular Crafts

At Harappa, copper melting debris, the various bone-associated slags, and to some extent pottery firing assemblages, tend to be isolated and not intermixed with debris from other crafts. In contrast, all of the lithics—chert, talc/steatite, semi-precious stone, possibly groundstone—are usually found together, and often in association with shell-working. There are thus hints of differences in the organization of the pyrotechnological crafts vs. the extractive-reductive crafts (cf. Vidale & Balista 1990). This pattern seems to be somewhat true for Mohenjodaro, although it is perhaps not quite as clear.

It is also not yet clear if the forming stages of the pyrotechnological crafts of pottery, faience, and copper were located near their firing stages or not, although some forming tools were found in the excavations of the updraft pottery kiln (kiln 100) on the north-west corner of Mound E. Certainly there is extensive evidence for forming stages near to pottery firing areas at Mehrgarh and Nausharo (C. Jarrige *et al.* 1995; Méry 1994; Miller 1997b).

"As I (Miller) noted above, there is some evidence to indicate that firing of talc/steatite took place near to its forming stages, as represented by the talc-coated clay containers found together with talc/steatite and other lithic debris in the general debris levels of the south-west corner of Mound ET. If any of the pyrotechnologies were linked with the extractive-reductive industries, the talc/steatite complex seems the most appropriate, and such an organizational association, if proven, gives us clues to the development of the tremendously complex talc and faience industries (Vidale & Miller, 1999). In this light, the possible evidence for faience manufacture found in this same area is extremely provocative. The identification of the various processes producing

the various bone-related slags is of great importance, in order to identify where the various talc and faience materials were produced—in isolated workshops or near to other crafts”?

The Organization of Production Areas

We have lost our tidily regimented ‘industrial quarter’ on Mound F, and instead have longer-term use of this area for smaller-scale pyrotechnological production, probably of pottery. This long-term use is itself interesting however, as it calls to mind the Berkeley project’s suggested long-term occupation of the north-west corner of Mound E at Harappa by a group of potters. However, there are some areas with evidence for production of pottery on almost an ‘industrial’ level. These are the north-east corner of Mound ET at Harappa, and especially DK-G area at Mohenjodaro, both of which show evidence for considerable pottery production. The question becomes whether or not these areas represent long-term use of an area for smaller-scale production, as for Mound F and the north-west corner of E at Harappa, or whether they truly represent the contemporaneous use of many kilns. If contemporaneous, were the potters squatting in an abandoned area, as suggested for DK-G at Mohenjodaro (Mackay 1937-38; Pracchia *et al.* 1985), or using an occupied part of the city deliberately set aside for pottery firing? Only future excavations will answer these questions.

Excavations on the south-west slope of Mound ET at Harappa provide evidence for organizational patterns of a different kind. As Kenoyer and Meadow have discussed, the recent HARP excavations here revealed evidence for the manufacture of a variety of apparently ‘elite’ objects all within a relatively small area, including chert weights; steatite seals and other objects; agate and other semi-precious stone beads; ivory and shell objects, perhaps including shell-inlaid wooden furniture; and possibly faience objects. Although no actual workshops have been found as yet it is clear that they were located nearby. This close association of so many crafts is perhaps indicative of a true craft-working quarter. Such localization of the manufacture of valuable objects might also facilitate the control of craft production—if nothing else, by the taxation of products or raw materials moving in or out of the quarter, or through the nearby city gate in the massive wall around ET (Kenoyer 1997a, 1997b: 269; Meadow & Kenoyer 1997).

Comparisons with Mohenjodaro

Finally, there are glimpses of differences between Harappa and Mohenjodaro in their craft industries, at least for high-temperature crafts. At both sites, the areas where pottery and terracotta objects were fired are the most numerous and the most widespread of the pyrotechnologies. This is not surprising, given the predominance of these items in the finds from Indus sites. However, while the areas of most intense production at Mohenjodaro are marked by huge heaps of pottery wasters (misfired *vessels*), even those areas with known pottery kilns at Harappa have very few pottery wasters. Mackay and Vidale have both commented on a similar lack of pottery wasters at Chanhudaro (Mackay 1943: 67; Vidale 1989: 178). Why the potters at both Chanhudaro and Harappa seem to have had considerably better control over their firings than the potters at Mohenjodaro is not clear. The double-chambered updraft kilns used at both Harappa and Mohenjodaro are almost identical. Nor do there seem to be significant differences in chronology or in objects being fired, as at least some of the kilns at both sites contained the same pottery type, Pointed Base Goblets (PBGs), which are a characteristic artefact of Period 3C at Harappa.

There is considerably more evidence for stoneware bangle production at Mohenjodaro than

Harappa, in spite of an effort on my (Miller's) part to locate any such production sites at Harappa. This fits with the neutron activation data from the bangles themselves, which indicate that bangles made at both Mohenjodaro and Harappa are found at Harappa, but only bangles made at Mohenjodaro are found at Mohenjodaro (Blackman & Vidale 1992).

(Note that copper melting is the most restricted in distribution of all of the craft industries at Harappa.) However, we must remember that the surveys at Mohenjodaro did not systematically cover the entire site. This caution also holds for the evident predominance of data for glazing and faience manufacture at Harappa; in addition, these latter industries are particularly difficult to assess, as we still know little about the manufacturing installations used. Comparisons between the extractive-reductive industries (lithics, shell, etc.) are even more precarious, as my surveys at Harappa were not focused on these crafts and were also more rapid than those at Mohenjodaro (Miller 1994a).

In sum, not only does craft production distribution provide us with information about the structure of Indus cities in general and the social relations of people within them, but it may also shed light on the technical development of and links between various crafts. It further contributes to our knowledge of the specializations of the peoples of the Indus cities, and the exchange networks between them (Vidale and Miller 1999).

Here we may take note of a refreshing ethnographic viewpoint. Lahiri (1993:130) says, "...Here, I have to acknowledge that Badli Ram's vivid sense of Sihi's rich mythical associations which have shaped local attitudes to metallic waste suggested to me that at Harappa, a monumental centre of the Indus civilization, this was the only possible way of making sense of the contextual associations of many slag specimens. This third millennium BC city, situated in the Sahiwal region of Pakistan, was an important copper/bronze craft centre of its area although its immediate hinterland is minerally barren. Most of its copper was probably procured from north-east Rajasthan, heart of the metallurgical complex of Ganeshwar-Jodhpura sites, and as such, there is no evidence of primary ore smelting at Harappa itself. In the process of secondary manufacture, however, some slag and miscellaneous waste was generated and, as Vats' excavations at Harappa (1940: 254ff) underlines, these are primarily found in the post-cremation urns of its various mounds....Slag was being produced at Harappa in the course of artisanal crafting and manufacture. However, its contextual association suggests that it was considered more than just a by-product of smelting and manufacture. When appropriated in funerary rites and rituals, it was divested of its technological meaning and reconstituted as a cultural signifier of beliefs which cannot be as clearly spelled out as at Sihi but are related to death and possible after-life".

She forcefully concludes, "Generally, works on metallurgy in antiquity tend towards monolithic model made up of an evolutionary development of metalcraft with a unifunctional use of artefacts and raw materials, within which cognitive archaeology has no place. All those components that cannot be subsumed within this paradigm are dismissed as anomalous/discrepant products of technological/resource constraints/determinants and, hence, unworthy of interest in themselves. My purpose has been to show that some such elements of metal technology in India can, through the microcosm of ethnography and early literature, both rich sources of cognitive information, be located within historically documented cultural choices, an artisanal ecosystem that is based on resource conserving principles as well as folk traditions and historical events" (Lahiri 1993:130).

I would like to comment here that though such ethnographic studies undoubtedly enrich our understanding of the past, one cannot ignore the evolution of technology - unilinear or multilinear - in the past.

Reassessing Interpretations of Urban Structure and Craft Manufacturing at Indus Cities

Summarizing their paper, referring to their Fig. 8, Vidale & Miller say that it is possible to view this as a multi-step process; for the Indus region we do not conceive of such steps as historical phases, but rather as diachronic trends which superimpose one onto the other, with the previous trends remaining more or less active. Nevertheless, there is a clear shift in the emphasis on these trends over time, moving in an anti-clockwise direction on our graph.

Vidale and Miller (1999) explain the four trends that they discern, "Trend 1 represents the basic technological attitude of a stabilized village community to experiment and innovate with their basic, local resources and raw materials. For the Indus, such a trend should have been well defined at the end of the Mesolithic period. Trend 1 is thus responsible for the creation of the basic technological styles and strategies of early settled communities. Trend 2 would be distinguished by the procurement and exploitation of rare and exotic raw materials for the production of status symbols. Manufacturing techniques remain relatively simple. We witness this trend in the Early Neolithic graves of Mehrgarh and their ornaments made from lapis lazuli and seashells. In Trend 3, manufacturing techniques become more elaborate and are applied to local raw materials as well as rare and valuable materials. Greyware pottery is an example of the former, while examples of the latter include the introduction of copper/bronze working, the systematic firing of carnelian, and the elaborate seashell bangles of the Early Regionalization era of Mehrgarh. For the Indus region, Trend 3 appears fully displayed in the second half of the 4th millennium BC. Trend 4, finally, affecting the whole course of the 3rd millennium BC and brought to its extreme consequences in the Harappan phase, is distinguished by unusually high levels of technical elaboration in craft industries based on cheap, relatively local raw materials.... So, as a generalized model of social structure, each Trend brings about important consequences for the society as a whole. In Trend 1, adaptation to settled agricultural economies required millennia of experiments and innovations with the local resources and raw materials. This probably allowed a first, basic definition of major production specialization trends in the Indus communities. The resulting differentiation of roles, professions, rights, and ranks in these communities may be seen as a powerful stimulus towards an efficient integration of village/town communities (compare Durkheim 1893). In Trend 2, the use of exotic materials as prestige signs perhaps indicated the capability of establishing and maintaining not only trade networks, but also strategically important alliances with other settled communities and tribal groups. At a symbolic level, the use of foreign, exotic materials coming from the outside world might suggest a growing consciousness of the cultural boundaries of an ancient society. This might promote a progressive identification of the community itself (compare Helms 1993). Trend 3 is dominated by the consequences of the elaboration of pyrotechnologies, allowing not only the production of new powerful symbols of status, but also the manufacturing of new tools and weapons, and, ultimately, the storing and managing of exchange value through dynamic, perhaps aggressive strategies. Trend 3, therefore, witnesses a growing hierarchical differentiation of communities.... Trend 4, as we have seen, is permeated by the need to articulate new roles and ranks in urban communities, creating new complex hierarchies but mediating this process with the need to maintain a pervasive social consensus. As discussed, this is reflected in the personal ornaments of the Harappan phase, with status indicated by hierarchies of base materials and social unity by standardized form/shape" (H.M-L. Miller 1997b; compare Davis 1989).

Finally we would like to quote below the table Kenoyer & Miller (1999) have prepared

Table 5.2 Metal and Non-metal Objects of the Indus Valley Tradition
(Table 5.4 of J.M. Kenoyer)

Object categories Neolithic	Early food producing era Early chalcolithic		Regionalization era*	
	Non-metal objects	Metal objects	Non-metal objects	Metal objects
Vessels	ceramic, stone	-none-	ceramic, stone	-none-
Mirrors	-none-	-none-	-none-	-none-
Ornaments				
beads, pendants	stone, shell, bone, ceramic	copper/ gold	stone, shell, ceramic	copper/bronze/ silver/gold
bangles	ceramic, shell	-none-	ceramic, shell	copper/bronze
pins/awls	bone, antler	-none-	bone, antler	copper/bronze
finger/toe rings	-none-	-none-	? shell	copper/bronze
fillets/head bands	? beaded, fabric, leather	-none-	? beaded, fabric, leather	-none-
composite/inlay	stone	-none-	shell, stone, faience	-none-
Inscribed/Design				
seals, tokens, plaques	stone, bone, ivory, ceramic	-none-	stone, shell, bone ivory, ceramic	copper/bronze
Tools				
arrow-heads	stone (microliths)	-none-	stone (microliths)	copper/bronze
points	bone, antler	-none-	bone, antler	copper/bronze
axes	stone	-none-	bone, antler	copper/bronze
adzes	stone	-none-	stone	copper/bronze
chisels	stone	-none-	stone	copper/bronze
drills	stone	-none-	stone	-none-
blades	stone	-none-	stone	copper/bronze
spear points	stone	-none-	stone	copper/bronze/ silver
small knives/razors	stone	-none-	stone	copper/bronze
fish-hooks	-none-	-none-	-none-	-none-
sickles	stone blades	-none-	stone blades	-none-
saws	denticulated stone blades	-none-	denticulated stone blades	-none-
Figurines				
animal	ceramic, stone	-none-	ceramic, stone	-none-
human	ceramic, stone	-none-	ceramic, stone	-none-

* Sites of the Nal Phase have copper and silver tools and weapons similar to those found in the Harappan phase of the Integration Era. There are problems with the actual dating of Nal burials and settlements.

showing the evolution of crafts and technology in the Indus region. It graphically brings out changes in the whole region through the different socio-economic stages of Early Food Producing Era, Regionalisation Era and finally to the Integration Era.

INDUS TRADE AND MELUHHA

Intimately related with the problem of copper metallurgy is trade. What was being imported and exported, including ores and metal? The Mesopotamian texts refer to trading and supply centres like Dilmun, Magan and Meluhha. Where are these places to be located? There is still quite a bit of controversy about these places. In this connection we would discuss the views expressed by Chakrabarti, Ratnagar and some others. As we would not like to pass judgements on who is right or who is wrong, we propose to place the different views objectively.

Dilip Chakrabarti has written a book specifically on the trade, entitled *The External Trade of the Indus Civilisation* (1990). And therefore it will be worth quoting it extensively. Chakrabarti (1990:143) states that among the more important raw materials copper has been supposed to come from Oman, because of the presence of nickel as a trace element in the ore of the region and the high nickel content of the Indus copper bronze objects. He however notes, "This issue, as we have already emphasised, cannot be solved easily, at least not without extensive ore-artefact correlation studies on the Indus objects. As David Muhly writes: 'Nickel is so common that it cannot possibly be used to identify an ore from a specific source'. On the other hand, one has to explain an apparently widespread Harappan presence in the Omanese peninsula. In 1986 S.R. Rao went to the extent of suggesting that 'copper seems to have been purified in the Lothal workshops and exported in the form of bun-ingots. One of them found at Lothal is of 99.8% purity and it is arsenic-free unlike the Mohenjodaro ingot'. This idea seems to be based on the fact that Oman copper is not arsenic-free. But as Rao accepts the idea that Lothal imported Oman ore, he assumes that this ore must have got purified at Lothal because out of 300 copper objects analysed at Lothal not one contained arsenic. In this connection Tosi speculates that the Indus people made a kind of base in Oman for further voyage up to the Egyptian coast. About the location of Ras al-Junayaz where an inscription with four Indus characters was found incised on the shoulder of a painted jar, he writes: 'This locality occupies an even more strategic position on the coastal route from Karachi to the Horn of Africa'. He goes on to add, it seems increasingly likely that the Indus civilisation contributed more to oceanic seacraft than any of the other proto-urban civilisations of the Middle East".

Dilip Chakrabarti further says, "We have already drawn attention to the significance of Afghanistan as a positive source of Indus copper, lead and silver, although each of these metals is easily procurable in Baluchistan, Rajasthan and Gujarat. Ratnagar writes that there was no indigenous production of silver in India until a fairly late period, and that the Harappan silver came from Mesopotamia. This statement does not appreciate the extent to which we have argentiferous galena in the lead-zinc deposits of Zawar and Agucha in Rajasthan. Besides, silver objects are found as early as Nal. The idea of Harappan tin coming from the relevant mines in the southern part of Central Asia is an acceptable one, and we doubt very much if the Harappans could get all the tin they needed from any fluvial deposit. The nearest major source of tin in India is Bastar in the southernmost part of Madhya Pradesh, and although tin is now commercially exploited in that region it is very doubtful if the Harappans were getting their tin from Bastar. On the other hand, Shortughai is conveniently located to receive Central Asian tin ores. The only snag in this hypothesis is that tin does not seem to be at all significant at Shortughai which

does not even possess a significant amount of lapis, although its location is quite close to the lapis-bearing area. Tin has also been in Iran. Whatever the source of Harappan tin, Central Asia or/and Iran, it must have come, partly at least, from such an external source. A long-distance trade in raw materials, even bulky materials like ore, should no longer be considered a theoretical impossibility. A recent piece of pertinent research relates to the understanding of such trade in copper ore in the prehistoric Iranian plateau. It seems that from the Anarak mines, near Sialk, copper ore, in this case a natural arsenic alloy, was exported to Sialk I-III, Hissar I-II and Tepe Yahya VI (end)-IVC. This distribution virtually covers a very large section of the Iranian plateau. There was local smelting of ore in each case, each site having its own technological process and distinctive artefacts. The trade was only in ore.

"It is not easy to suggest what the Harappans received from Mesopotamia in the Indus-Mesopotamia trade. Mesopotamia's general exports have been called invisible exports consisting of items such as fish and grain. These could not have been her exports to the Indus. David Muhly writes that judging from Ur texts, the Mesopotamians offered chiefly raw wool and garments made from this wool, as well as silver, in exchange for the products of the East. On the basis of the Mesopotamian literary references Muhly also makes a detailed list of the items imported by Mesopotamia from Meluhha, which has been generally associated with the Indus civilisation: lapis lazuli, carnelian, gold, silver, copper, ebony, ivory, tortoise shell, a bird thought to be some sort of chicken, peacock, dog, cat and monkey" (Dilip Chakrabarti 1990: 143-48).

Let us now try to locate the oft-mentioned sites of Dilmun, Magan and Meluhha.

Dilmun, Magan, Meluhha

Dilip Chakrabarti reviewing the literature on this problem says, "The literature on this theme has grown steadily in recent years. The identification of Dilmun with Bahrain is perhaps universally accepted. In 1944 S.N. Kramer identified it 'in all probability' with south-western Iran. Later on he located it in the Indus valley. In 1946 P.B. Cornwall critically reviewed Kramer's opinion: '... it is essential to recognise at once that the cuneiform references to Dilmun fall into two distinct categories. 1. Historical, commercial, epistolary, dedicatory, and astrological inscriptions; 2. Sumerian literary compositions. In the former, Dilmun is a definite geographical locality - of that we may be certain.' In the latter it is a fabulous land; a strange antechamber to the spirit world. That the two Dilmuns were thought of as being somehow identical is very likely; but I suggest that Dr. Kramer should not have decided the location of Dilmun merely on the basis of Sumerian literary compositions, especially since the evidence gleaned from the other class of source material points decidedly to the equation Dilmun = Bahrain.... In 1952 Cornwall reformulated his earlier opinion: the identification with Bahrain island and part of the Saudi Arabian province of Hasa may be accepted without reservations....The Danish researchers in Bahrain and the adjacent areas in the Persian Gulf have clinched the issue in favour of Bahrain".

About Magan and Meluhha, Dilip Chakrabarti (1990:148) says, "Gelb's own inference is that Makan is the southern shore of the Persian Gulf and of the Arabian Sea; it denotes Arabia, extending east of ancient Sumer up to and including Oman. Meluhha, according to him, is the northern shore of the Persian Gulf and of the Arabian Sea; it denotes Iran and India, extending east of ancient Elam and Ansan up to and including the Indus valley. In other words, Meluhha was a generic name standing for certain regions east of Mesopotamia, which also included the Indus valley".

Dilip Chakrabarti (1990:148) emphatically says, "Regarding Meluhha this is a general

conclusion to which we would like to adhere in the present stage of knowledge. Kinnier-Wilson suggests the following identification of Makkan, which has a bearing on the identification of Meluhha as well. He points out that the stone used in the Gudea statuary is not diorite but a substance which occurs in the Tul-i-Marmar area in the general region of the Iranian oil-fields in the south-west corner of Iran. He does not seem to have any doubt about this identification, but the point is that if south-west Iran, or a part of it, stands for Makkan of the Mesopotamian literary sources, Meluhha will stand for regions further to the east, up to and including the Indus valley. This is very unlikely to stand for the Indus valley alone"

Ratnagar's review of this problem appeared (1995:115-27) much later than her book (1981). She says, "Harappan trade has been a popular subject for the last two decades. 'Multi-national' excavations and explorations in Iraq, Iran, and the countries of the Gulf have resulted in a voluminous literature on the cultural connections between various regions from the Euphrates to the Indus. An exhaustive discussion is not possible here, and I can only refer to an earlier monograph (Ratnagar 1981) and indicate the more important themes and emphases, or revisions of views that have emerged since then.

"Here we will deal only with the long distance overseas trade, and situate this phenomenon in the wider framework of complex and multiple-stranded cross-cultural interactions which prevailed in the later third and earlier second millennia BC over an area much wider than that marked by Harappan trade routes....The intercultural trade embraced contrasting places and cultures, even though all regions are characterised as arid and semi-arid, and the rainfall in all cases except Kachchh and Kathiawad and the relevant tracts of northern Afghanistan being below 300 mm per annum. Sumer and Seistan had relatively high agricultural potential, in contrast to the environs of Tepe Yahya in south-west Iran or to northern Bahrain. The Upper Gulf could offer only dates and pearls for trade whereas in the Lower Gulf (the Peninsula of Oman) occur rich veins of copper and hard dark stones like gabbers and dolerites. Perhaps the Harappans were the only participants who had easy access to fine timbers. The largest of the culture areas, the Harappans incorporated areas with marine resources, others with forestry, and yet others known to be agriculturally rich zones".

Ratnagar (1995) notes that "Mesopotamia and South Asia represent literate and urbanised societies, the 'Bronze Age' in every sense of Gordon Childe's usage, but not so the Kulli, or groups at Yahya or in Oman. She finds it of interest that the various culture areas did not always exhibit the closest ties with those nearest them. It has long been appreciated that Mesopotamia, the agriculturally richest and the most populous area, had huge quantities of grain, oil, and woollen textiles to offer. It was also perhaps the home of the most skilled metallurgists. But it was the largest importer of metals, stones and shells (having none of these locally), most of which came from South Asia, the eastern terminus of the trading circuit. Besides being procurers and suppliers of so many trade items, the Harappans may well have been the most accomplished seafarers, given their privileged access to the best boat-building timbers (these have up to recent times been imported by seafarers of the Gulf from India). It hardly bears repetition that the movement of heavy and bulk items like stone, metal, and timber is immensely cheaper by water than by land..."

As noted in chapter 2, Ratnagar does not seem to concede to what Dilip Chakrabarti has said above, "This point about the two urbanised termini of the trade comes across vividly when we consider the trade in silver. Little silver has been found in the intermediate areas of Southeast Iran, Seistan, or the Gulf - except for two silver artefacts at Shahr-i-Sokhta in Seistan and two

silver beads in an Oman grave. It had earlier been argued (Ratnagar 1981: 144-46) that the Harappans, the only people of protohistoric South Asia to have used silver on a substantial scale, imported this metal, most likely from Mesopotamia. A regular movement of silver from the Assyrian merchant colonies of Cappadocia to Mesopotamia is well documented for the period between 1920 and 1750 BC and texts from Ur which refer to silver being taken overseas by merchants to buy copper in Dilmun (clearly an entrepot) date to the time of Rim Sin of Larsa or 1822 to 1763 BC. It had also been pointed out that silver occurs in the two large Harappan settlements of Mohenjodaro and Harappa, but is almost totally absent at the other sites....Another argument for Mesopotamia as the source is that, even earlier, around 3500-3000 BC and also later, silver and lead were used on a substantial scale in Mesopotamia and Elam. One example is provided by the Early Dynastic III Royal Cemetery at Ur, with a truly exceptional amount of silver (Moorey 1985: 114 ff, 122 ff). Second, we now have a run of radiocarbon dates from the silver-lead bearing localities of Dariba, Agucha, and Zawar, near Ajmer in Rajasthan, which testify to mining in the later first millennium BC rather than earlier (Craddock *et al.* 1989). The only earlier mining is attested to at Dariba, but these dates are post-Harappan, viz. later second millennium BC". (for silver also see chapter 2).

Ratnagar thinks that, because in Dilmun (in the Bahrain archipelago) the Ubaid pottery was found in this region that was actually made in southern Mesopotamia (Oates *et al.* 1977), Mesopotamia sea voyages had begun by 4000 BC.... "All this evidence together prompts the adoption of a long chronology for the Barbar/Dilmun culture. The major argument for a short chronology has been the absence in the temple and settlement of Bahrain of carved chlorite containers of the early series (see Kohl 1986: 368), which date to Early Dynastic II-III. Such vessels do, however, occur on Tarut Island not far away, and as grave goods. Carved as they are with intricate 'mythological' elements, these containers in some cultures may well have been of exclusively funerary use".

Referring to the scale of the trade, Ratnagar (1995: 123) says, "We have two glimpses of its scale from the cuneiform texts. The first concerns a trade transaction (see Roaf 1982) in which some 18,000 kg of copper were involved. In the second, consignment of 2,380 'gur' (a capacity measure) of barley goes to Magan (see Ratnagar 1981: 80). If, as is commonly accepted, a 'gur' was 240 litres or 180 kg of grain, then 2,380 'gur' was a gigantic amount, and its import requires careful thinking out".

She further says, "Knowledge about metal ores and techniques and about pyro-technology appropriate for faience production may have spread wide, as Childe had often said. Yet the socketed spearhead of Oman does not appear to have influenced Harappan tools which lacked sockets and strengthening central midribs. Most intriguing is the use in Turkmenia of several kinds of alloys - copper-lead, copper-silver, silver-copper, copper-lead-arsenic/tin, and copper-tin-arsenic - were in use (Masson 1988: 99) but in spite of 'contacts' there appears to be no such experimentation with alloying in the Harappan civilization (where tin bronze was the alloy in general use, an alloy which apparently was scarce in Turkmenia). Do we interpret this as a function of availability of metals, or as resistance to the spread of certain techniques?" This statement is however difficult to understand in view of use of lead, tin and arsenic in Harappan coppers.

ANALYTICAL DATA AND DISCUSSION

In recent years Dales, Kenoyer and Meadow have extensively excavated Harappa. The metal analyses

are still in progress. I report here some recent data (Kenoyer & Miller 1999; Dales & Kenoyer 1989: 21-22).

Metallurgical Analysis

The analysis of the copper artefacts from Harappa is being conducted at MASCA (University Museum, Philadelphia) by Vincent C. Pigott, Stuart J. Fleming and Elizabeth Reistoffer. At the present time eleven artefacts have been studied to determine the elemental composition of the metals, the microstructural features of the metal and the technology involved in the production of each specific object. Preliminary findings indicate the presence of relatively pure copper artefacts, objects made from arsenical copper and one object made from tin-bronze. The techniques of manufacture and metal processing include casting, cold hammering, annealing and possibly drawing. After all of the samples have been studied it will be possible to determine the chronological sequence and variation of metallurgical techniques at Harappa. These samples represent the first set of metals from a major urban centre that have been collected in a way that can provide new information about the chronology of metal working techniques in the Indus civilization.

Preliminary analysis of some of the precious metals has been started using minute samples from specific artefacts (the actual artefacts are in Pakistan in the Harappa Museum Reserve Collection). These studies are being done by Dr. J. Mark Kenoyer and Dr. Jim Burton at the University of Wisconsin. To date, three samples have been tested using the Electron Microprobe at the Department of Geology, U.W., Madison. These samples indicate the use of almost pure gold (94-95%) and a small amount of silver (5-6%) in two of the samples. These samples were taken from fragmentary pieces of what appear to be hammered gold leaf. Another object appears to be an unfinished bead made from a combination of both silver and gold. This technique of mixing gold and silver has not been well documented for the Indus civilisation and further studies will be made of this object.

In the next chapter we will discuss the enigmatic Copper Hoard culture.

CHAPTER 6

COPPER HOARDS METAL TECHNOLOGY

CONTENTS

- THE COPPER HOARD CULTURE
- COPPER HOARDS IN KUMAUN
- THE GANESHWAR CULTURE

THE COPPER HOARD CULTURE

A variety of copper tools, mostly in caches, hence the name Copper Hoards, were accidentally discovered from a number of sites in Uttar Pradesh, Bihar and Madhya Pradesh. Copper was the main metal used by all the protohistoric cultures in India and therefore it is no surprise that a variety of tools cropped up from sites as far away from each other as Shalozan in north-west Pakistan, Bhagrapir in Orissa, and Kallur in the south. The tool types were equally varied: rings, flat and shouldered celts, trunnion axes, anthropomorphs, swords, double-edged axes, harpoons, socketed axes, etc. As most of the discoveries were chance finds, no other associated artefacts were reported.

This sort of amorphous evidence spread over most of the subcontinent provided a congenial ground for all types of speculations to thrive. Barring the identification of the Aryans, no other archaeological topic has been the subject of so much conjecture and speculation. Heine Geldern (1936:87-88) theorised that the Copper Hoards represent the remains of the Aryan migration in India, but Pigott identified them with the Harappan refugees. Heine Geldern claimed that the trunnion axe came from Transcaucasia via Persia in c.1200-1000 BC. Originating from the Danubian region, the axe-adze also reached India via Iran in c.1200-1000 BC and the antennae swords were influenced by the Koban examples dateable to c.1200-1000 BC.

In a brilliant paper in 1951, Lal cleared a lot of the mess by an objective analysis of the total evidence. He showed that the trunnion axes, the Fort Monroe sword, the socketed axe and axe-adze never occurred in the doab but were confined to the north-western part of the subcontinent. As a corollary, he showed that the harpoon, the barcelt and the anthropomorph (Fig. 6.1) were never found west of the doab. He also pointed out that the antennae swords of the doab were cast as a single piece, unlike the Koban specimens. Here it may be pointed out that stray examples of socketed axes and adzes are reported from Chanhudaro, Mohenjodaro and even from Mundigak Period III, from much earlier contexts than c.1200-1000 BC as claimed by Heine Geldern. It is, therefore, obvious that this Aryan-equation is not tenable (Agrawal 1982).

With a lot of the extraneous types weeded out by Lal, the main Copper Hoard types that

remain are: flat and shouldered celts, barcelts, double axes, antennae swords, harpoons, hooked swords and anthropomorphs. The two double axes from Bhagrapir (Orissa), though up to 40 cm wide, are only 1-3 mm thick, and therefore they could never have been used as axes. Recently, Amita Ray has found five such double axes from the Kangsavati valley in Bengal. Gordon (1958) has quoted such types being used for land grants in historical periods. Flat and shouldered axes reported from all over India and abroad are too elementary to be treated as diagnostic types.

The hooked sword appears to be a distinctive type with median ridge and a hook chiselled out from the tang. In the Harappan examples, generally a hole is used for hafting and not a hook. The Navdatoli specimens do not have a barb and the median ridge is quite diffused compared to the Copper Hoard examples. The hooked sword has been found associated with the other diagnostic types *e.g.* the anthropomorph, the antennae sword and the harpoon at Sarthauli, Bahadurabad, Fatehgarh and Niori.

The most distinctive and enigmatic type is the anthropomorphic figure (Fig.6.1). As the name shows, it does seem to suggest a human form and because of this it has been identified as a ritualistic object. I have examined several specimens from different museums and found three main features in the anthropomorph: externally sharpened and incurved forearms; plain hind limbs; and a thickened head. It was perhaps used as a missile to kill birds as the sharp arms could cut the bird, the thick head could stun it and the incurved arms could entangle and bring it down. The head was the thickest part and the extremities had thinner cross-sections. An experimental model, when thrown, went in a whirling fashion and seemed to make a trajectory which made one suspect a boomerang-like effect. Sankalia, however, thought that such a device would be too complicated to have been used by a simple folk, but then the boomerang was invented only by the simple Australian aborigines.

A fragmentary piece of an unidentified object with a convex end and two broken side-lugs from the Harappan levels of Lothal has been compared with the anthropomorph from the doab. It would not be mechanically feasible for the Lothal specimen to break so near the body, had it longer arms. In the whole range of hundreds of Harappan artefacts, this piece alone has the alleged resemblance with the anthropomorph.

The harpoon (Fig.6.1) is like the mid-ribbed sword, except that it has barbs pointing backward and a hole at the end of the barbs. There are two varieties of harpoons: one, cut from a thick sheet and the other, cast in a double mould. Harpoons could have been used for killing fish or big game as shown in a rock-shelter in Mirzapur.

The antennae swords (Fig.6.1) of 42-75 cm length have antennae-like bifurcation at the hilt end and they are mostly confined to the doab zone. At Kallur, in Andhra Pradesh, were found 'antennae hilted' swords with very short antennae compared to the doab specimens. However, it is now known that a thief had hidden these swords at the find spot at Kallur and their original provenance is not known. From Mehsana (Gujarat) four antennae swords were recently reported. Their antennae are beaten flat and appear more like fans. The doab antennae have the length-to-blade ratio of about 5, whereas for the Chandoli dagger (Fig.6.2) it is only 1.6. Moreover, the antennae swords of doab are cast as one piece, whereas the Chandoli specimen has the hilt cut-split and beaten back, perhaps to prevent a wooden handle from slipping. Thus both technologically and functionally the doab specimens cannot be compared with that of Chandoli.

The antennae of 10 cm length or more would be a positive handicap in wielding it as a weapon of offence such as a sword. I had once proposed that these swords were probably

fixed to clefts in logs of wood inside a big pit, with their tips pointing upwards and the game which was stampeded into such pits was pierced by these swords.

It is therefore obvious that the hardcore of the Copper Hoards consists only of the anthropomorph, the harpoon, the hooked sword, and the antennae sword. These types are found associated together: for example, at Bisauli harpoons and anthropomorphs occur together; at Bithur antennae swords and harpoons are associated; antennae swords and anthropomorphs were found together at Fatehgarh. The hooked sword was associated with the other three types at Fatehgarh, Sarthauli, Bahadurabad and Niori.

Some flat celts had bull figurines engraved near the butt-ends: this unique discovery was reported by Misra from Midnapore (Hardoi district). Some of the celts here weighed 2 kg.

The barcelt is about 60 cm long with a bevelled edge and a thick body. Its sturdiness and length suggest its use as a crowbar for digging copper ores. The use marks on these barcelts do indicate their use against hard surfaces. They have been reported from sites in copper-rich Bihar.

The eastern group of the copper implements comprises simple types like shouldered and flat axes and rings which are ubiquitous in most of the Chalcolithic cultures. The only distinctive type in this group is the barcelt which is generally absent from the main doab group. Recently these tools have been termed as the *Indian* Copper Hoards. One may ask a basic question here: if all these Chalcolithic, Harappan, Neolithic and the Copper Hoards cultures were so closely related, did they form part of a single culture? Obviously not. Even the different Chalcolithic cultures have a distinct personality and a spatio-temporal distribution. Therefore such long distance and tenuous correlations cannot be accepted.

At many sites, *e.g.* Bahadurabad, Nasirpur, Bisauli etc., the Copper Hoards have been reported and so also the OCP; but the problem is how to define the OCP. With its spouted, handled and black painted vessels and chert blades, Saipai appears to be quite unique. Moreover, such association needs further confirmation from other sites.

In Haryana and Rajasthan region, as also in western Uttar Pradesh, there appears to be some Harappan influence. Except for a reported harpoon from Mitathal, no doab types have been discovered from Haryana or Rajasthan. The *parasu* seems to be a type of this area. It has been found at Mitathal during excavations and from the Khurdi hoard, Rajasthan, as also from Kalibangan.

Though Lal (1951) emphasised that the Copper Hoards were not alloyed with tin, yet Smith had reported some high-grade bronze examples from the British Museum. Subsequent analyses did not reveal any tin alloying. But in our recent analysis, 46% artefacts showed arsenic alloying (up to 7%) which marks them apart from the Chalcolithic artefacts where no arsenic alloying was resorted to (see Rapp 1986, however). On the other hand, only a small percentage (8%) of the analysed Harappan artefacts shows arsenic alloying (Fig. 3.1).

The Copper Hoard people used closed moulds for casting, employed cold work and annealing; however, no pots and pans were known.

The identity of the Copper Hoards in the doab seems to be established beyond doubt. The Bihar variety of copper artefacts are simpler basic types (*e.g.* flat celts), except for the barcelt. Keeping in view the proximity of copper ores in Bihar, and the simplicity of the tool types, one may claim precedence in time for them. The mid-doab has its own distinctive and advanced types without parallels in other areas. This uniqueness may reflect a local origin of the culture.

As mentioned earlier, Heine Geldern associates the Copper Hoards with the Indo-Aryan

migration of c.1200-1000 BC or earlier. Pigott saw in these Copper Hoards the remains of the Harappan refugees on their eastward march. The OCP cultures of Haryana, the Rajasthan and the western Uttar Pradesh do show Harappan and Sothi influences, but they are not related to the Copper Hoards of the mid-doab. M.P. Joshi (1995-96:23-31) says, "While closing this discussion, it would be appropriate to add here that in the present state of our knowledge it is an open issue as to the identification of the authors of the Copper Hoard Culture of the Ganga-Valley. There is no doubt that they are associated with the authors of the Ochre Coloured Pottery (OCP) as evidenced at Saipai. However, it is also true that there are many places, for example, Kumaon and Nepal, where anthropomorphs have been found, but not the OCP. Discovery of the anthropomorphs in Kumaon and Nepal leaves no room for doubt that is a community of the coppermiths called Tamtas. They are traditional coppermiths". Lal (1972) associates the Copper Hoards with the Mundari-speaking Australoid tribes of the primeval Uttar Pradesh but Y.D. Sharma identifies them with the Late Harappans. Sankalia sees West Asiatic influence even in the OCP, especially in the handled and spouted pottery of Saipai. I have suggested a Central Himalayan affiliation (Agrawal 1999). Thus identification of the authorship, at present, is purely a game of guess-work.

As no ^{14}C dates are available for the Copper Hoard culture, no chronologies are being proposed here.

COPPER HOARDS IN KUMAUN

Central Himalayas seem to have played a significant role in the metal technology of north India (see details in chapter 8). Here we are only discussing the evidence related to the Copper Hoards. There are two significant finds of Copper Hoards from Kumaun, one from Bankot and the other from Haldwani, as discussed below. (For a comprehensive discussion, see Agrawal & Kharakwal 1998 and Agrawal 1999.)

The Bankot Copper Hoard

Bankot village (long.79°52' E; lat.29°45' N), tehsil Berinag, in Pithoragarh district is situated about 130 km northwest of Pithoragarh town. The area is easily approachable from Almora town via Seraghat. The village is situated on a dolomitic mountain slope running eastwest, along the Saryu river.

In 1989 at Bankot, a hoard of 8 anthropomorphic copper objects was discovered while digging a stone quarry close to the Bankot Inter College. At present six anthropomorphs are kept in the custody of Shri Chanchal Singh Bankoti, at Bankot, and one is under treatment in the Govind Ballabh Pant Government Museum, Almora for chemical preservation. According to the villagers, they were stacked one over the other on a tray like stone slab. The following table gives their description.

These anthropomorphs have an oval shaped head and their arms spread horizontally across the body. The lower part of their body is almost flat, slightly widening near the feet. A concave depression is there between the feet. The edges are generally thick and roundish, but in one case both the arms are broken.

The Bankot copper anthropomorphs appear local in character. We do not know why they were placed in a stone quarry. It is obvious that they had been buried intentionally. It may be noted however that there are no traces of mining and smelting activity within 10 km area of Bankot.

Table 6.1 Dimensions and weight of the Bankot anthropomorphs

Anthropomorph No.	1	2	3	4	5	6
Breadth including arms (in cm)	30	30	30.5	30	30.5	14
Total height (in cm)	24	23.5	24	15	14	24.5
Thickness (in cm)	1-3	1.5-2	1-3	1.5-2	2-3	2-3
Weight (in kg)	3.30	2.50	3.45	2.15	2.46	2.40

The Bankot copper anthropomorphs contain 98% copper, 1.22% iron, and a minor impurity of arsenic (Pant 1991: 41). After examining these artefacts it appears that they were made in an open, single mould, probably made of stone as their measurements show some uniformity also in the finishing as well. Their obverse side shows some gas cavities, which suggest that they were made in an open mould, without green poling, and left unfinished. Since there is no copper mine at Bankot, it may be suggested that these anthropomorphs could have been manufactured at Kharahi or Rai-Agar. The so-called Bankot anthropomorphs could simply be copper ingots as their weights suggest. We need to note here that the Bankot specimens are a bit crude type and have stub like arms, unlike the typical anthropomorphs of the Doab. They are either in the range of 3.4 ± 0.1 or 2.4 ± 0.1 kg (Agrawal & Kharakwal 1998).

According to local report (*Amar Ujala*, 8th May, 1986: 3) an anthropomorph was found at Haldwani in Nainital district similar to the ones reported from the Gangetic valley from time to time (Joshi 1990: 14). Whether it was a local production cannot be said as we could not examine the artefact. Nonetheless it is a significant discovery of the remains of Copper Hoard culture in the foothills of the Kumaun Himalaya.

THE GANESHWAR CULTURE

In my view, the Ganeshwar Complex, holds clue to the Harappan copper artefact supply, hence a detailed treatment is given here. The Ganeshwar culture has been variously grouped under the Chalcolithic, the Copper Hoards and even the Harappan categories. We have included it in the chapter on Copper Hoards, as these copper artefacts were found in hoards. The Ganeshwar complex artefacts probably represent a manufacturing activity. They probably catered to the Banas Culture and the Harappa Culture. More than 5,000 artefacts have been reported from a small area. Their nearness to the rich copper ores of Rajasthan perhaps explains the abundance of artefacts here. It may however be noted that no typical Ganga Doab type anthropomorphs, swords etc. have been reported from the Ganeshwar area. The following discussion is mainly based on Agrawala (1984b).

In 1977 Agrawala located a Copper Age site at Ganeshwar (Agrawala 1978) about 15 km south west of Nim-ka-Thana, a tehsil headquarter in district Sikar, 75 km from the actual Khetri copper deposits of Ahirwala-Chiplata. Baleshwas and Dariba mines are within 10 to 15 km from Ganeshwar. From this site he discovered some copper arrow-heads (without any holes) and a spearhead (Agrawala 1984b).

The pottery of Ganeshwar bore resemblance to that from Jodhpura in the district of Jaipur about 40 km, as the crow flies, from Ganeshwar. The ^{14}C date of Jodhpura OCP suggested the 2500 – 2000 BC bracket for its later phase indicating, thereby, that the beginning of this ware may be pushed back to 3000 - 2800 BC. Jodhpura is situated on the right bank of river Sabi which once flowed into the Yamuna. It was through this river that the so-called OCP people are likely to have moved to the Yamuna basin and also into western U.P. Beside the Sabi, the river Kasaunti, originating from the Dariba copper hills (of Ganeshwar region), flowing near Mothooka copper mines and the town of Narnaul, joined the river Sabi in Haryana. A number of Jodhpur-Ganeshwar pottery sites have been discovered all along the river Dohan. Here, too, they have discovered copper objects and the Ganeshwar type of pottery. The Dohan river, flowing to the west of Narnaul once reached Charkhi-Dadri and the Mitathal region where Suraj Bhan has already discovered a copper celt, a chisel, a ring and a copper harpoon. In fact, the supply of copper to the site of Mitathal seems to have been from the Ganeshwar-Narnaul region. A number of copper deposits are still available all along the Dohan river as well (Agrawala 1984b).

Agrawala (1984b) emphasises that, Ganeshwar, as a site, is ideally situated on the source of one of the streams of the river Kantli which is further fed by other streams from Kanwat-Thei-Khandela, all located in the copper zone of the Shekhawati region. They also discovered dozens of OCP sites along various nullahs and streamlets of the Kanwat and the Khandela, originating from Ganeshwar and discharging into the main Kantli. The pottery from this zone has been called Ganeshwar pottery and is freely available in the Sikar district of Rajasthan. The Dariba copper mines have also yielded Ganeshwar pottery. The Kantli river is at some places, 2 to 3 km in width and it must have made possible, movement from Ganeshwar to Kalibangan and other Indus centres of the west. A number of Kalibangan type sites along the Drishadvati river, such as Siswal, Sherpura and Sothi are well known.

Agrawala's explorations and excavations at Ganeshwar and its vicinity in 1979 yielded a rich collection of copper objects, about a thousand in number. These include 60 flat celts, more than 400 arrow-heads, 50 fish-hooks, dozens of blades, spearheads, rods, nails, bangles, chisels, etc. all of which belong to the Indus typology and not a single specimen is of the Copper Hoards type of the Ganga-Yamuna Doab. The use of fish-hooks and arrow-heads suggests that the economy of the Ganeshwar people was still largely dependent on fishing and hunting. The beginning of Ganeshwar culture, on the basis of pottery analysis, may well be pushed back to 3000 – 2800 BC. Later on, when a considerable demand for copper from the Indus sites arose the Shekhawati region of Rajasthan may have supplied the copper ore as well as the copper objects, both to the pre-Harappan and the Harappans, such as to those in Kalibangan. In the context of the Ganeshwar-Kalibangan interaction, the discovery is important. So also are the few Ganeshwar shards with deep zigzag incised lines in the interior portion, since they recall a similar tradition present in pre-Harappan pottery of Kalibangan and Kot Diji. A few specimens of Reserved Slip Ware, including a bowl-on-stand, from Ganeshwar, also deserve special mention.

The copper celts from Ganeshwar measure 20 to 25 cm in length and weigh between 1 and 1.5 kg. Most of them have round indentation marks on one side. It is perhaps significant to note that the indentation marks on the Ganeshwar celts are near the butt end whereas those on the Chalcolithic celts from Kayatha and Navdatoli in Madhya Pradesh are on the body of the celt, much below the butt end. The copper celts from Ganeshwar do not show any alloying with tin; tin was not available locally. The Geological Survey of India laboratory at Jaipur has given the following analysis of a typical copper celt:

Copper	97%
Silver	0.2%
Lead	1%
Arsenic	0.3%
Tin	0.01%
Nickel	0.6%

It is likely that the Kurada celts with four marks were prepared in the Ganeshwar region, along with copper bowls, five with channel-spouts. The bowls are also important since it was the trade with West Asia which might have induced the Ganeshwar people to prepare copper bowls in imitation of the channel spouted bowls from Iran, as Sankalia had earlier suggested. It is to be noted that Kurada was situated on a trade route which runs west via Ganeshwar, Kurada-Pokaran-Phalodi-Jaisalmer-Kot Diji, etc.

The copper arrow-heads from Ganeshwar were cut out of thin sheets, perhaps with a scissors-like instrument as the arrow-heads are quite thin. They were mounted on wooden sticks or reed shafts with a vertical slit at one end, and fastened with the help of a white glue which is still to be seen on most of them. At some places, the marks of decayed wood are seen quite clearly. The copper percentage in the Ganeshwar arrow-heads is 96.5; arsenic being 1 per cent and tin only 0.2 per cent.

Agrawala suggests that the Ganeshwar people seem to have been the original inhabitants of the Khetri copper-belt region and, therefore, the copper artefacts were not products of itinerant coppersmiths. The entire area is rich in copper ore and people must have tapped the local sources to begin with for their main occupations though they resorted to limited agriculture and made use of wheel-made pottery. It was their surplus wealth, in the form of copper ore and copper objects, which subsequently reached the Indus sites. The picture will be clear only after the entire dried-up bed of the Kantli has been thoroughly investigated, from Ganeshwar till the point it joined the Drishadvati in Ganganagar district. Copper celts and inverted V-shaped arrow-heads occur in the pre-Harappan levels at Kalibangan as well, a fact which suggests their supply from the Ganeshwar-Khetri region. The Ganeshwar type of arrow-heads are available from the Harappan levels at Banawali, in Haryana, as well.

Ganeshwar Complex Typology

Agrawala and Kumar (1993:125-35) have described some of the Ganeshwar Complex types as follows.

Arrow-heads: Cut from thin copper sheets, like those of Indus sites, the Ganeshwar arrow-heads are rich and varied in size and shape. Most of them are of the barbed variety. Quite a number have a curved tip which is very unusual. They were probably meant for hunting a flock of birds. One copper arrow-head of this kind was excavated from Harappan levels at Banawali, Haryana. None of the copper arrow-heads from Ganeshwar has a perforation for hafting. But contemporary arrow-heads from Bagor (Misra 1970, Fig. 11.3) (district Bhilwara, Rajasthan) were provided with two holes each (Misra 1970). This allowed them to be fixed to the wooden shaft with the help of a thin wire. The Ganeshwar variety of copper arrow-head (without holes) was found in negligible number at Kalibangan, Lothal, Harappa, Mohenjodaro and Chanhudaro (Marshall 1939: Pl. CXLII, no. 13; Mackay 1938: Pls. CXXI, CXXVII, CXXXIII; Vats 1940: 383-84. Pl. CXXV, nos. 13-14). There are approximately 400 arrow-heads of this style from

Ganeshwar alone.

Agrawala and Kumar think that the discovery of microliths with copper arrow-heads at Ganeshwar suggests that the people of Ganeshwar, though they had developed a metallurgical technology, were still in a hunting stage. With rich copper mines nearby, they were able to exploit and successfully work this local resource as early as the third millennium BC.

K.K. Tripathi of the Geological Survey of India has analyzed an arrow-head from Ganeshwar: copper 96.5 per cent, silver 0.3 per cent, arsenic 1 per cent, lead 0.03 per cent, tin 0.2 per cent, nickel 0.04 per cent, zinc 0.25 per cent, iron 0.2 per cent.

Spearheads: The Ganeshwar copper spearheads are generally very thin. There are, however, a few thick examples. Comparable objects were also found at Harappa and Mohenjodaro. They were attached to wooden shafts before actual use.

Fish-hooks: The Ganeshwar copper fish-hooks, numbering about 50, are usually not provided with a tang. Small fish-hooks were also found at Harappa and Mohenjodaro in the early levels (Mackay 1938: Pls. CXXXII, No. 21 and CXXIV, No.29; Vats 1940: CXXV, no.28). Similar fish-hooks were recovered from Banawali as well.

Spiral-headed pins: Ganeshwar also yielded a few fragmentary pins which were characteristic of Harappan Culture.

Celts: The copper celts from Ganeshwar contain only a nominal quantity of tin as shown by the aforementioned details furnished by the chemical Laboratory of the Geological Survey of India at Jaipur.

The average weight of a Ganeshwar celt is approximately 1 to 1.5 kilograms. All these flat celts were prepared from moulds by the *cire perdue* technique. The butt portion of the celts has round indentations in groups of four, five, six, eight, nine, 12 and as many as 15 different combinations of one, two, three, four and six dots. The varied permutations and combinations of dots recall somewhat similar marks on the Chalcolithic celts from Navdatoli and Kayatha (Ansari and Dhavalikar 1975: 150). At Kayatha these celts were assigned a ^{14}C date of 2000-1800 BC. There was also incised pottery from these levels. Copper celts with circular impressions also come from Copper Hoard sites in western Uttar Pradesh (Thaplyal and Shukla 1976; Agrawala & Kumar 1993).

Thus with such a rich repertoire of copper artefacts and abundant mineral resources, the Ganeshwar Complex seems to have played a pivotal role in supplying copper artefacts and ingots to the Harappans and the Banasians, and perhaps has nothing to do with the Gangetic Copper Hoards.

In the next chapter we will discuss the Chalcolithic cultures which were essentially non-urban in character.

CHAPTER 7

CHALCOLITHIC METAL TECHNOLOGY

CONTENTS

- INTRODUCTION
- THE BANAS CULTURE
- THE KAYATHA CULTURE
- THE MALWA CULTURE
- THE JORWE CULTURE
- CHEMICAL ANALYSES

INTRODUCTION

The Chalcolithic cultures in India include non-urban, non-Harappan cultures characterized by the use of copper and stone. These cultures make their first appearance at the turn of the second millennium BC and are eventually replaced by the iron-using cultures. Unlike the Harappa culture, which was marked by a striking uniformity despite its spread over a vast area, these cultures show a distinct regional identity, probably determined by smaller ecological units. Southeastern Rajasthan gives rise to the Banas culture, the Malwa region to the Kayatha culture and the mid-Gangetic valley to the Ochre Coloured Pottery (OCP) culture. The main difference among these cultures lies in their characteristic ceramics, though economically they have a similar status. A limited amount of copper and an abundance of lithic blades mark most of these cultures (Misra 1969, 1970, 1997; Misra *et al.* 1995, 1997). Below we give a brief account of these cultures with emphasis on metal technology. The most recent excavations in Rajasthan have been conducted by V.N. Misra at Balathal, near Udaipur. Gilund, a Banasian site, is being again excavated by Possehl and Shinde.

THE BANAS CULTURE

This culture is named after the river Banas on whose banks the Banasian sites were found. Though more than fifteen sites of the culture are known in the river valleys in Southeast Rajasthan, excavations were conducted only at Ahar, Gilund and Kayatha.

The Banas culture is marked by a painted Black & Red ware (Fig. 7.1). The eastern part of Rajasthan is greener and more hilly in contrast to the western part which is arid and flat. Relief is provided only by the extensive sand-dunes. The Banas and the Chambal drain the area, almost perennially.

The area around Udaipur is like a big basin enclosed by hills and there is only one broad

opening out of this on the north-west side. Ahar, the type site of this culture, is located in this basin which has good soil, rainfall and plentiful game even today. There are schist and quartz outcrops which they used in house building and copper ores for their tools.

Ahar is a fairly big mound: 500 x 270 x 13 m and was anciently known as Tambavati (a city of copper), indicating its richness in copper. The thirteen-metre deposit at the site has been divided by the excavators into Periods I and II- each period is further subdivided into a, b and c phases.

Jawari (a millet) is known from the pottery matrix of Period II. There are also impressions of long-grained rice. No other grains, charred or otherwise, have been found. Animal bones, however, are in plenty; turtle, fish, goat, sheep, deer, pig and cattle were eaten. Bovines dominate the animal remains.

The longer axes of the houses were aligned north-south and the shorter, east-west. The plinths were invariably made of schist over which mud or mud brick walls were built up. The walls were decorated with quartz cobbles. The longest house discovered was ten metres long and appeared to extend further, though normal sizes are 7 x 5 m and 3 x 3 m. Timber was used minimally—perhaps for the central post to support a thatched roof. The floors were made either of burnt clay or clay mixed with river gravel. Bigger houses had partition walls and *chulahs* (hearths) were an invariable feature of the kitchen. Quartzite saddle querns formed part of the kitchen equipment.

At Ahar only copper was used and no stone blades, but the same culture had a developed blade industry at Gilund, which is just 80 km away, and at Kayatha. At Ahar five axes (Fig. 7.2), one knife blade, one sheet, a bangle and two rings of copper have been found. The copper technology however seems to be poor, compared to the Harappans. The axes have blowholes and there is no evidence of work-hardening.

Agrawala (1984a) claims, the copper objects from the excavation at Ahar near the town of Udaipur, it is significant to note, were prepared from the copper ores available near Ahar, the type site of Ahar culture datable to 2200 -1000 BC bracket. We have been able to locate, old copper is very well attested to by the heaps of copper slag lying scattered within a radius of 100 to 150 m between the Matoon and Umra mines. The discovery of a copper furnace at Ahar is therefore not surprising. The copper objects include bangles, rings, celts, etc. (Sankalia *et al.* 1969: 199-203). The copper celts from Ahar are, however, comparatively thin and small in size, the maximum length is 13 cm, the width of the butt end is 8.3 cm and the maximum thickness is 0.5 cm from Sadali in Chittor district - six copper celts (Agrawala 1979: 91-93) which measure between 20 and 25 cm in length and weigh about one kg each, as compared to about 240 gm of weight of the Ahar celts were discovered. This proves beyond doubt that different varieties of copper celts were prepared. The determining factors were to a great extent, the quantity and quality of copper ore available locally. The copper mines of Bhinder and Bhadesar located near Bari Sadali are not far from Padaliya. Significantly, these mines are richer than the Matoon-Umra mines (Agrawala 1984a: 156).

From Ahar were discovered in 1955-56, copper objects in the form of a thin knife blade from the lowest levels and two thin copper blade pieces from levels datable to 1500 BC or a little earlier. Significantly, they bear resemblance to several specimens from Khurdi or Kurada, and Mitathal in Rajasthan and Haryana respectively (Agrawala 1980: 89-91) and have been called *parasu* by different writers.

The Ahar choppers (*parasu*) also bear resemblance to a curved blade from the Pre-Mature Harappan levels at Kalibangan. In fact, this was an object of great utility and bears resemblance

with the modern *gandasa* of frequent use in the Punjab, Haryana, U.P. etc. for cutting stalks of wheat, barley and rice plants as well as long thick grass for animal fodder. This Kurada Hoard from a site called Kurada, in the district of Nagaur of Rajasthan, contained at one time, twenty-one such copper blades whereas now only four are known and are preserved in the Government Museum at Jodhpur.

The thin blade of the copper knife from the lowest levels at Ahar also recalls similar specimens from Harappans and other Harappan sites. Thus, the copper tools from Ahar had both the Harappan and the non-Harappan Chalcolithic traditions which is quite understandable because Ahar was a late contemporary to the Indus civilisation (Agrawala 1984a: 158).

Agrawala (1984:158) emphasises that we must also take note of the total absence of Ahar type of copper objects at Kayatha or Dangawada in Madhya Pradesh where the inspiration for copper technology seems to have come from some source other than Ahar. Agrawala's presumption is based on the fact that the copper celts from Kayatha and Navdatoli in Madhya Pradesh, as well as from Kurada (Agrawala 1979) and Ganeshwar (Agrawala 1978: 123-24) in Rajasthan have round indentation marks whereas such marks are conspicuous by their absence on the celts both from Ahar and Padaliya.

Agrawala mentions three copper arrow-heads with two holes each, from 2800 – 2000 BC levels at Bagor in the Bhilwara district of Rajasthan. A similar type of arrow-head has been excavated at Indore, on the outskirts of the town of the same name in Madhya Pradesh. Such arrow-heads are conspicuous by their absence in Ahar sites.

The available ^{14}C dates suggest a c.2000-1400 BC bracket for the Banas culture.

Balathal

Misra *et al.* (1997) have recently excavated the Balathal site, near Udaipur. It seems to be the earliest Chalcolithic site of Rajasthan. It has yielded evidence of fortification, incipient urbanisation and a rich repertoire of pottery, and some copper artefacts (Fig. 7.12) too.

They report about the antiquities found at the site, "Although the Chalcolithic phase has provided excellent evidence of architecture, suggesting a high degree of economic prosperity among the inhabitants, large quantities of ceramics of high technical quality, vast amounts of animal bones, mainly of domesticated animals, and plentiful remains of charred seeds of cultivated crops, it is rather poor in manufactured objects, other than ceramics. The first two seasons yielded about a dozen copper-bronze objects comprising choppers, knives, razors and one specimen each of a chisel, a tanged and barbed arrow-head, and a six-petalled flower-like object and bits of copper, some terracotta bull figurines and beads, beads of semi-precious stones, numerous stone querns, grinders, hammer-stones, small terracotta balls and a few microblades, microliths and fluted cores. In the last two seasons, however, the number of metal objects and beads of semi-precious stones are very few. The only noteworthy finds of metal objects are one specimen each of a six-petalled flower-like object, a point, an ear-stud and a razor blade" (Misra *et al.* 1997: 35-60).

About the chronology of the site Misra *et al.* inform that "The first ten dates are derived from samples coming from Chalcolithic levels and they range from 3800 BC to 1800 BC. Barring the first date, which is nearly 1,200 years older than the next oldest date, all other dates are reasonably consistent. Thus, excluding the first date, the duration of the Chalcolithic culture ranges between 2600 and 1800 BC. However, so far we have only two dates, including the deviant one, from the lowermost levels.

"Therefore, there is a strong possibility that when more dates become available from the

lowermost levels, the antiquity of the settlement will go beyond 2600 BC. Even on the basis of presently available dates, Balathal would be the oldest known village outside the domain of the Indus (Harappan) civilization. Two dates (Nos. 11 and 12) come from layers of the Early Historic period but they are too old for this period. It is possible that because of the disturbance caused by the Early Historic occupation of the long-abandoned site, older samples got into the layers of the Early Historic period and therefore the dates are older than expected. If that be the case, then the upper limit of the Chalcolithic occupation goes to the middle of the 16th century BC. The dates (Nos. 13 to 15) come from the Early Historic levels and they range from 340 BC to AD 130, *i.e.* covering the time from the Mauryan to Kushana periods which is consistent with the archaeological data”.

About the sequence at the site, Misra *et al.* (1997) report, “In Phase A the architecture is very simple, consisting of circular mud floors plastered with cow dung and lime as seen in trench HX2. Over these floors probably huts of wattle-and-daub were raised, as indicated by burnt clods of mud. However, the discovery of two deep silos lined with grass and lime plaster in trench HX2 shows that the inhabitants produced surplus food grains. This is significant because the area excavated of the early phase is very small. Associated with the silos and even outside of them, a number of large, heavily worn querns were found. The use of stone and mud brick for construction was not known in this phase.

“There is a marked change in the size of structures and the materials and techniques used in their construction from the beginning of Phase B. The architecture of this phase is marked by the extensive use of semi-dressed and undressed stones and mud bricks. Four architectural phases have been identified in this cultural phase. Phase I is so far represented only by two small walls - one in trenches FY2 and GY2 and the other in trench 0F2. Both these walls are made of stone. Phase II is the most prosperous. It is best represented by the fortified enclosure and multi-roomed Complex I. These are characterized by large and massive walls of stone, mud brick and mud. There is evidence of incipient planning of the settlement. The fortified enclosure is located in the centre of the settlement surrounded by residential quarters. Both these structures are indicative of considerable prosperity and, seen along with modest structures of Complex 3, HX2, and D2, provide evidence of stratified economic and social organisation. Phases III and IV represent economic decline.... The evidence from the excavated areas suggests the entire site came under occupation only in the middle phase (layers 17 to 14) around 2400 BC. This phase also witnessed a remarkable increase in prosperity, best exemplified by the architecture, probably as a result of contact between the Balathal people and the Harappans of Gujarat”.

THE KAYATHA CULTURE

The Malwa region of Madhya Pradesh is a plateau drained by the Narbada, its affluents, the Tapti and the Mahi, which debouch into the Arabian Sea, and by the Chambal and the Betwa which join the Yamuna in the north. Present annual rainfall averages about 105 cm and the nights are cool even during summers. Most of Malwa is covered by a fertile black soil; the region is so fertile and congenial that throughout historical times kings vied with each other to occupy it. Though some scholars believe that this black soil may have attracted the Chalcolithic settlers too, the evidence suggests that the Chalcolithic man confined himself to the narrow alluvial strips of the rivers. With his meagre copper implements he could not have ploughed the sticky black soil. In fact, the alluvial strips imposed ecological restraints on surplus food production and as a result the Chalcolithic cultures could never urbanize despite their copper technology. Kayatha,

situated on the bank of the Kalisindh, an affluent of the Chambal gives the culture its name.

The most distinctive feature of this culture is its pottery in three fabrics. The most predominant is a thick, sturdy Brown Slipped ware painted in violet or deep red. The designs are generally linear, painted on the rim. Bowls and basins and globular jars with concave necks are the main shapes, though storage jars are also found. The pots are made of a fine, pinkish well-levigated clay and majority have a ring base, though it does not appear functional as the base protrudes beyond the ring. The ring base recalls Pre-Harappan Sothi types. The deep bowl with a beaded rim and the globular jar are common between the Sothi and the Kayatha cultures; even the fabric and surface treatment of these two wares have a striking resemblance. Some affinity with the Harappan ceramics has also been claimed though it appears very tenuous to sustain.

The Kayathans, it seems, were quite well off in copper as from one pot alone twenty-eight copper artefacts were recovered. The two copper axes with a sharp cutting edge and a lenticular section are the finest examples (Fig. 7.3) in the Bronze Age India. The axes are cast in a mould unlike the later Chalcolithic specimens which were just hammered to shape in central India and the Deccan. A chisel is also reported from here.

A Bagorian copper arrow-head was found in the upper levels of the Kayatha.

The Kayatha people were expert in using bronze objects. They had moulded copper celts with punch-marks like the Harappan or Navadatolian celts. They were using bronze bangles—28 of them were found in a hoard. Two necklaces, two celts, 28 bangles and several thousand steatite beads were found from one rectangular room. Some storage jars, all in one line were also found in the room. This was either a storeroom or a vendor's shop. This assemblage of celts and bangles (28 in number) was the biggest copper hoards found in Malwa (Wakankar 1982:224-37).

The Kayatha culture is known from forty other sites in the Chambal valley, though the only one excavated is Kayatha. It has some affinity with the red ware storage jars of the Harappans. The discovery of copper bangles and semi-precious bead necklaces from pots, both at Kayatha and Mohenjodaro, as also the steatite beads, lends some support—albeit tenuous—to the claim of a Harappan affinity. Some similarities with the Sothi or the pre-Harappan culture, however, seem to be there too. The Combed ware and the red Slipped ware of Sothi and Kayatha have some affinities. Sankalia has therefore surmised that when the Harappans pushed out the pre-Harappans from Rajasthan, they colonized Malwa. The name Kalisindh, on whose banks Kayatha is located, nostalgically recalls Sind (the Indus), the original home of the pre-Harappans.

The discovery of pots containing bangles and beads was made from a small area, perhaps from the same house. It may indicate a sudden desertion of the site, probably under attack. The invaders, however, did not occupy the site as there is a sterile layer of desertion intervening between the Kayathan and the succeeding Banasian deposits at the site.

The Kayatha culture is essentially bracketed between c.2000 and 1800 BC, as indicated by the ¹⁴C dates (uncalibrated). The Malwa culture succeeds the Kayatha and the Banas cultures.

THE MALWA CULTURE

Malwa, in western Madhya Pradesh, has two main parts: the northern Vindhyan scarpland and the Deccan lava plateau in the south. The Vindhyan scarpland rises from 450 to 580 m. Though the Chambal and its tributaries arise within 30 km of the Narbada, they drain northwards into the Gangetic system, whereas the Narbada debouches into the Arabian Sea. There is a sharp contrast between the Vindhyan and the Deccan lava landscapes which is reflected in the present-

day settlement patterns also. The Vindhyan country is more rugged, more arid and with little soil cover. The vegetation is marked by poor grassland and acacia scrub.

Malwa is the main seat of the Malwa and the Kayatha cultures and even the Banas culture extended here. The Malwa culture is marked by the Malwa ware (Fig. 7.4), a buff or orange slipped pottery painted in black or dark brown, use of copper and stone tools, and small settlements of wattle and daub huts. Sites of the Malwa culture have been reported both from Madhya Pradesh and Maharashtra. The best known excavated sites are Eran, Nagda, and Navdatoli in Madhya Pradesh and Inamgaon in Maharashtra.

Navdatoli, meaning the village of the boatmen, is situated on the southern bank of the Narbada. On the other side of the river is Maheshwar where also extensive traces of the settlement can be seen. They were extensively excavated by Sankalia *et al.* in 1953-54 and 1957-59. Whether the Chalcolithic man was attracted by its scenic beauty or not, the site does present a beautiful panorama of the tall Vindhyas in the north and the low Satpura hills in the south and the wide expanse of the Narbada. For a considerable distance, the Narbada flows through narrow gorges, but here the valley is broad with considerable alluvial deposits on either side of the river. It clearly shows that the Chalcolithic technology was not capable of agriculturally producing much from the black cotton soil, and hence they selected this spot with broad alluvial stretches.

The Chalcolithic habitation at the site extended over the four mounds at Navdatoli, though not simultaneously. The Chalcolithic period of the site is divisible into four phases. Phase I is marked by the Banasian type of black-and-red ware; Phase II by the cream-slipped ware; in Phase III appears the black-on-red ware; Phase IV is characterized by a coarse red ware in association with the lustrous red ware somewhat akin to that of the post-Harappan Gujarat cultures. But all through these four phases, the Malwa ware continues.

Navdatoli has a uniquely rich ceramic tradition. Sankalia claims that Navdatoli has the richest repertory of designs amongst all the Chalcolithic cultures, including the Harappan. The Malwa ware is a painted pottery in black or brown over a buff or orange slip, but the fabric is thick due to the use of chopped husk. A thinner variety of this ware which becomes dominant at Eran also occurs at the site. Dhavalikar calls it the Eran fabric. Main shapes of the Malwa ware are lota, channelled spouts and pedestalled goblets.

Navdatoli has given ample evidence regarding the food habits of the people too. Charred grains of wheat (*Triticum vulgare compactum*), barley, and rice (*Oryza sativa* L) were found only in Phases II and IV. Black gram, green gram, lentil (*Lens culinaris Medicus*), grass pea (*Lathyrus sativus* Linn), linseed, ber (*Zizyphus jujuba Lamk*), amala (*Phyllanthus embellica*) are the other vegetable products used by them. There is also evidence that the people ate beef, venison and pork.

A variety of stone tools, which were generally made of milky chalcedony, were used by these people. It is evident that each household made its own tools. For obtaining blades, the crested-guided-ridge technique was used. Pen knife, blunted backed, serrated and parallel-sided blades, trapezes and lunates were the main tool types and over 23,000 tools were discovered.

Though few in numbers, flat copper celts (Fig. 7.5) with convex cutting edges, arrow-heads, spearheads and chisels form an important part of the tool repertory. Except for the mid-ribbed sword, which must have been cast, other objects appear to have been hammered to shape. Artefacts like blades, bangles and rings were also made of copper. The coldwork and annealing techniques were known to these people. A comparison of the trace chemical impurity patterns of ores and these artefacts has been carried out to locate the copper mines used. Tin was alloyed up to 3% and lead to about 2% (see Fig. 3.1).

THE JORWE CULTURE

The Jorwe Culture was spread over Maharashtra. Most of the area comprises the Deccan plateau; only the river valleys have open plains with a rich soil cover. Rainfall ranges from 50 to 100 cm, but varies from year to year and there are frequent droughts. The Jorwe ware (Fig. 7.6) is the hallmark of this culture. It has a red or orange matt surface painted with geometric designs in black. It has a fine fabric and is well baked. The spouted jar (Fig. 7.7) with a flaring mouth, the carinated bowl and the high-necked jar with a globular profile are the main Jorwe vessels for heavy use like the storage jars. Platters, dough plates and even lamps were hand-made in coarse red/grey ware. Some pots are zoomorphic (animal-shaped).

Though the Jorwe Culture sites are not rich in copper, copper axes from Nevasa (Fig. 7.8), Jorwe (Fig. 7.9), and Inamgaon have been reported.

Inamgaon: A remarkable and unique kiln to fire pottery has been discovered at Inamgaon, a Chalcolithic site. Built in stone foundations, it is like a huge trough of clay about 1.7 m in diameter. Oval clay cushions with a hole in the centre and grooves on the side were placed over the fire chamber at a depth of 60 cm to provide outlets for hot gases. Air ducts radiated from the centre of the kiln. Though the Harappan kilns were built on similar principles, yet their design and material were different.

A few polished dolerite axes and a prolific blade industry of chalcedony and agate comprised the lithic assemblage. Copper was used to make axes, chisels, knives, fish-hooks (Fig. 7.10), beads and bangles. A boat-shaped kiln to smelt copper ores has been identified at Inamgaon (Fig. 7.11). One interesting find of a copper punch has been reported from Inamgaon. It is 6.5 cm long and 1.4 cm thick. This was perhaps used for detaching stone flakes (Dhavalikar *et al.* 1988:726). Very few artefacts have been chemically analysed. An axe from Jorwe and a chisel from Nevasa show 1.8-2.8% tin alloying.

The ^{14}C dates (uncalibrated) suggest that the Jorwe culture is confined to c.1400-1100 BC, though at Inamgaon its late phase continues much later.

In the eastern zone are included the present states of Bihar, Bengal and Orissa. The excavated sites, however, are largely confined to Bihar and Bengal.

Chirand is located on the confluence of the Ganga and the Ghagra in district Saran, Bihar. Recent excavations have pushed back its antiquity into the II millennium BC. Period I at the site is Neolithic, free of metal; Period II is Chalcolithic; and Period III is marked by the appearance of iron. In the recent excavations, copper has been reported even from the top of Period I. Keeping in view the developed ceramic tradition, the cultural equipment of Period I is very similar to the Chalcolithic cultures. Copper artefacts are few and include tanged arrow-heads, a ring, bangles, antimony rod etc. Lithic-flakes, scrapers etc., abound in Period II. Polished stone axes, however, appear curiously enough as late as Period III. Bone points proliferate gradually from Periods I to III. Rice, fish, nilgai, pig and deer were the main dietary items.

CHEMICAL ANALYSES

Rapp (1986) has carried out chemical analyses of Chalcolithic artefacts. We have discussed these analyses in chapter 2.

In the following chapter we will discuss the role of the Central Himalayas in copper and iron technologies.

CHAPTER 8

CENTRAL HIMALAYAS, INDIAN ARCHAEOMETALLURGY
AND ETHNOMETALLURGY

CONTENTS

- INTRODUCTION
- LINGUISTIC DATA
- IRON AND COPPER IN CENTRAL HIMALAYAS
- TRADITIONAL TECHNOLOGY
- ETHNOGRAPHIC EVIDENCE
- CONCLUSIONS

INTRODUCTION

In this chapter we bring out the significance of the new data from the Central Himalayas and its bearing on the Indian archaeometallurgy. We also indicate the probable contacts with South-east Asia and the diffusion possibilities of metal technologies from there. The chapter also addresses itself to the role of the Central Himalayas as possible sources for both copper and iron for north India.

On the basis of technology, abundance of metals, mines used and tool typology, I had argued that in the Bronze Age India, the 3 main techno-cultural traditions (the Harappa culture, the other Chalcolithic cultures, the Copper Hoard culture) were essentially independent - temporally part-contemporary, but spatially disparate (Agrawal 1982a).

Generally in the dynamics of these Indian technological traditions, the Himalayas are ignored as isolated *cul-de-sacs*. Recent evidence, however, seems to indicate that this region may have played a more crucial role in the development of both copper and iron technologies. We discuss below the possible role of the Central Himalayas (the present hilly districts of Garhwal and Kumaun divisions of Uttar Pradesh [UP] in northern India) in the development of both early copper and iron technologies. Here I refer specifically to the Copper Hoard culture and zone B of Prakash and Tripathi (1986) of iron technology, as explained below (see chapter 11 for details).

The Gangetic alluvium has filled the foredeep caused by the Miocene orogeny of the Himalayas. As a result, there are no rock outcrops in this alluvium, hence no mineral bodies. The question then is from where the Copper Hoard culture obtained its supplies of copper.

Traditionally, the rich Bihar (Singbhum belt) ores have been identified as sources of copper for the Copper Hoards. It may still be true for the eastern Copper Hoard group. Not many trace element analyses are available to compare the impurity patterns of the Copper Hoards with different mines. No lead isotope analyses have been carried out either. However, one trait marks

the Copper Hoard artefacts of Central Ganga: About 50% of the artefacts analysed so far show a significant arsenic content (1-7%), but no tin whatsoever (Agrawal 1982a). Whether arsenic was deliberately added for increasing the hardness of the metal artefacts or it was an impurity present in the metal used is difficult to say. As arsenic minerals are rare in India even today, deliberate addition of arsenic seems to be rather a remote possibility. If it was an impurity, the possibility of Kumaun being the source of copper becomes stronger as the copper minerals there contain arsenic.

The possibility of a link between Copper Hoards and Kumauni sources of copper minerals becomes more plausible as at Banakot 8 lugged type anthropomorphs were found in a stone quarry, described in detail in chapter 6. Another evidence is that in these foothills a typical anthropomorph turned up at a scrap dealer's shop. Thus circumstantial evidence connects the Central Ganga group of Copper Hoards with Kumaun.

LINGUISTIC DATA

We discuss the linguistic data in chapter 9.

IRON AND COPPER IN THE CENTRAL HIMALAYAS

It is generally agreed that the beginning of the first millennium BC saw the advent of iron in India, though Chakrabarti (1992:68) likes to put it much earlier. Prakash and Tripathi (1986: 568-69) have identified 5 zones of iron working in ancient India. Zone B is northern India. The Painted Grey Ware (PGW) cultures may be credited with the introduction of iron in the Gangetic basin. The PGW distribution zone extends from the Punjab and Himachal Pradesh in the north, to Ujjain in the south, and from the Great Indian Desert of Bikaner in the west to Kausambi and Vaishali in the east. Western boundaries of the PG Ware have been further expanded to Bahawalpur state in Pakistan.

Here we will confine ourselves to the Zone B (Painted Grey Ware zone of north India). Elsewhere, we have shown that the Zone A (north west India) and Zone B (North India) have clear links (Agrawal and Kharakwal, chapter 4, 1998).

Not only archaeological, the literary evidence also indicates that iron was used in early I millennium BC in the Gangetic basin (Kosambi 1963).

Sources of iron

Kumaun has an old tradition of iron metallurgy and high grade ores from Lob and Agar have been reported and analysed (see Agrawal & Kharakwal, chapter 4, 1998). We have found a number of sites with iron ores, mining shafts, slags, kilns, etc. The British tried to start an iron industry in Kumaun in the 19th Century. There was a strong local iron smithy tradition till recent times. Lohaghat, Pithoragarh district, was known for a rust-resistant iron made out of the local ores.

Kumaun is known for its hoary metallurgical tradition. Copper, iron and lead were mined extensively in this region (Atkinson 1989: 259-98). The revenue records of the last century show that copper mining was a thriving industry in Kumaun. There are several rich copper ore sites in Kumaun, e.g., Rai-Agar, Bora-Agar, Askot and Ramgarh. In fact, 'Agar' is associated with ancient copper smithy and "Asur" and "Lu" with iron smelting sites.

"The iron ores found in Kumaun belong to either of the two varieties, the rhombohedral or the prismatic. The first is a peroxide of iron containing in its best defined type 70% iron and 30% oxygen" (Atkinson 1889:287). Scaly iron ore was mined at Ramgarh and Dhaniyakot

on the Koshi. Both yielded a good quality of iron. During the British period, Lusgani, Nathuakhan, Gulla and Satbunga were the principal mines in Naini Tal district. For the first 18 years of the their rule, these mines were leased to the headmen of the Agaris at a nominal tax (Atkinson *ibid.*).

The mines at Khetshari, Munia at Pali and Lakhanpur were quarried for prismatic iron ore. There were several mines located at Chiteli, Simalkhet, Gudi, Bailgaon, Bonigarh, Mehalchauri and Tilwara in Giwar patti of Almora district, which were exploited during the British rule. Simalkhet, one of the largest mines, had four entrances penetrating upwards of 100 m into the mountain. The ore here consisted of red hematite of a good quality.

In this chapter, we present the results of our recent explorations which raise a distinct probability of the iron technology coming to the northern plains through the authors of the cist-burials of Kumaun.

Early Metal Working Sites

We explored several early metal working sites in Kumaun, both of copper and iron. A brief description of metal associated sites follows.

Rai-Agar

Rai-Agar village is situated about 110 km north of Pithoragarh and about 100 km north-north-east of Almora on a Southeast slope of the hill, near Berinag in Pithoragarh. The area falls in the Lesser Himalayan zone and is enclosed by a beautiful forest of chir (*Pinus roxburghii*) and oak. The mineralisation here is confined to a narrow zone in the southern core of Syunt, near the villages Boragar, Batgal, Rai-Agar and Dol. The host rock for the base metal mineralisation is mainly dolomite and magnesite intimately associated with the talc. The magnesite near Boragar, Dol, Batgal and Rai-Agar shows disseminations of chalcopyrite, as medium to large irregular patches of isolated euhedral crystals, as disseminations, which can be easily seen in the modern workings of talc at Rai-Agar.

An ancient furnace was located at Rai-Agar village near the talc mine. There are three rectangular pits in two terraces in the village. Two of them, pits nos. 1 and 2 are dug in the upper terrace and the third one on a lower terrace, and is comparatively bigger. Their dimensions are as given in Table 8.1.

Table 8.1 Dimensions of furnace pits at Rai-Agar (all measurements in cm).

Pit no.	Depth	Length(E)	Length(W)	Breadth(N)	Breadth(S)
1.	170	180	90	80	35
2.	200	220	95	100	40
3.	250	280	240	230	64

Between the second and third pit, a wide channel like depression was noticed, which was probably used to take off the slag or smelted material from the second pit to the third pit. All these trenches have been made in north-south direction, whereas the connecting channel like depression is oriented north-east-south-west. Near this structure, there must have been a large amount of slag which was probably dumped in a circular heap. Even today, considerable amount of slag and tuyere pieces are lying scattered at the site. The villagers recount that it was a very

large heap, but with the passage of time it was destroyed by the local people. The trenches are partly filled with debris. At a depth of 25-30 cm, some charcoal (sample no. 68) was found. It has, however, given a recent date which means that some of these smelting activities continued till the 19th century.

On the small terrace-type fields and on the steep slope of the hill at Rai-Agar, the slag is lying even far off from the furnace location. Either it rolled down or the villagers disturbed it. According to the villagers, there were two similar furnaces in these fields which were dug away sometime in the past to make room for, agricultural fields. At present the agro-pastoralist Agri people, belonging to the Scheduled Castes of the Kumauni society, reside at Rai-Agar. According to them, it is a copper smelting furnace and their ancestors had been involved in mining and smelting activities in this area.

About a kilometre north of Rai-Agar, on the same mountain, is another old metallurgical site. There are similar trenches near Bora-Agar village.

The Rai-Agar mines were perhaps the most important copper mines of Kumaun during the British period. The ore was pyrites, in a matrix of indurated and sometime slaty talcose and steatitic schists enclosed in dolomites, which occurs in the schists in numerous strings. It can be seen in the modern talc mine at Rai-Agar. The direction of the strata is nearly east-southern, dipping at an angle of 45° to the north. The copper ore is accompanied by iron pyrite which are occasionally found in the pentagonal dodecahedron form (Atkinson 1989: 280). In 1850, Capt. Drummond found the lode to be about 2 ft (30 cm) wide, containing a good yellow copper ore, but with large proportion of its matrix being talcose, only 20% was metalliferous.

We collected a crystalline copper mineral sample from the soapstone mine near the smelting furnace, at Rai-Agar. It was analysed at Deccan College by X-ray diffraction method. It was found that it is a pure pyrite (FeS) ore which could have been used as a high grade iron ore.

Sira

Sira, an ancient mining area, is located in Barabisi patti of Pithoragarh district. It is situated at a higher elevation than the Rai-Agar mines. Atkinson states that the ore here too consists of copper pyrites, accompanied by iron pyrite in a gangue formed of dolomitic and talcose rocks (1989:281). The areas of Sira and Gangoli were under exploitation by the British and they are known for ancient mining. A copper sample was analysed at Calcutta in 1815 and found that it was mixed with arsenic and sulfur (Atkinson *ibid.*). In AD 1838, H. Drummond also examined these copper mines and he was of the opinion that special prominence must be given to the Kumaun iron works. Atkinson further states that copper mines of Sira, Gangoli (Kumaun), Pokhari and Dhanpur (Garhwal) were situated on a high cliff in the interior. The talcose and calcareous formations in which the ores were found occupy the high precipitous mountains which built the outline spurs of the principal ranges.

Kharahi

Kharahi patti is located close to the north of Almora town and extends between Binsar and Bageshwar. The area is known as a traditional centre of metallurgy from times immemorial. Atkinson (1981: 282) writes that the Gaul mine of Kharahi patti and Sor Gurang mines produced grey copper in small quantity. Tamtyura, Danochhina, Chaugochhina, Kharak-Tamta, Ghingarkhola, Binsar, Bhatkhola, Simsyari, Bihargaon, Uderkhani, Bilon, Agar, Gair-Sikera, Lob and Borgaon

were some of the places where metallurgy was practised in ancient times, according to the villagers, who now inhabit these places. The coppersmiths are known as Tamtas, who are thought to be responsible for introducing coppersmithy in Kumaun. It cannot be determined exactly when these smiths immigrated to this region. However, it is said that during the medieval period, a Chandra king of Champawat brought coppersmiths from Rajasthan to set up coppersmithy in Kumaun. Their first settlement is said to be at Gosni village near Lohaghat. Later on, the capital was shifted from Champawat to Almora, sometime in the first half of the 16th century (Joshi 1992:74).

Some families of coppersmiths were also brought to Almora to produce necessary items like tablets and stamps. According to the modern coppersmiths, during the Gorkha reign in the 18th and 19th centuries, two brothers Raibhan and Jaibhan were given land near Lamgara in Almora district to settle down and to produce traditional utensils. From there they used to go up and down to meet the demands of Gorkha kings at Almora. In course of time, some Tamta families shifted towards Kharahi patti, probably in search of copper ores. At that time, the Agri people, who are considered expert miners, were living in the Kharahi patti. It is told that Chanauli, Joshi Palari, Uderkhani, Chaugaonchhina, Bihar-gaon, Naial and Kharak-Tamta are the locations of first settlement of the Tamta people in Kharahi. The following places are believed to be ancient mining sites, where still traditional metallurgy is occasionally practised:

Khan-garh (Khano-ki-garh)	Copper
Agar	Copper
Chaugaonchhina	Copper
Dewaldhar	Copper
Lob	Iron
Pagna (near Bihargaon)	Sulphur
Shishakhani	Lead
Jhirauli	Magnesite
Palari	Magnesite
Chanauli	Magnesite

Copper pyrite, carbonate of copper and steatite were reported together in limestone outcrop by Capt. Herbert in Kharahi area of Almora. He found that these ores were free from the presence of arsenic, which more than the other materials deteriorates the quality of copper and is most difficult to remove (Atkinson 1989: 282).

During the field exploration, a few ore samples were collected from the Kharahi area. A sample (no. 124) of green colour from Khangarh village was analysed at Deccan College, Poona by XRD method, which shows that it is a very pure copper ore (malachite).

Asurchula

Asurchula (long. 80°12'E; lat. 29°38'N) is the name of a temple and a hill dedicated to Lord Siva. Both are located about 18 km north-east of Pithoragarh town at a height of 2,130 m AMSL. The hill is composed of quartzite and the Himalayan slate rocks, running north-east-south-west. The surface soil is calcareous, muddy brown in colour. Quartzite fragments are frequently mixed with the soil. This thin soil cover supports a beautiful thick forest of chir (*Pinus roxburghii*), burunsa (*Rhododendron arboreum*), oak (*Quercus incana*), *Alnus nepalensis*, deodar (*Cedrus deodara*), kaphal (*Myrica nagi*), and *Olea cuspidata*, along with many other species of the Inner Himalayan flora.

On the northern slope of the hill, Agar, Ban-Agar, Satgal, Chhana and other small villages are situated. Above these, at the lower edge of the forest, there are several terrace type fields on the hill slope between 1820 and 1840 m AMSL. A large amount of iron slag was encountered in the exposed sections of as many as 10 such terraces. At the Southeast corner of terrace no.1, there are remains of a rectangular structure measuring 7.70 x 6.70 m. It has been constructed using dressed and undressed quartzite stones. At present, only the plinth is remaining and all walls have collapsed. No artefacts were encountered around this structure.

There is a huge round quartzite boulder lying on the eastern part of terrace no.2 which is enclosed by dressed stones. A circular cup-mark, narrowing downwards, has been made in this boulder, whose diameter is 23 cm and depth 13 cm. It has a U-shaped bottom and the pit appears to have been used, probably for ore grinding purposes. These first two terraces are devoid of slag deposition. However, moving downwards to terrace no. 8, there is a slag deposition, rarely at a depth of more than 50 cm. At the eastern corner of terrace no. 3, the plinth of a rectangular structure measuring (north-south) 4.60 m, 5.60 m (east-west) and thickness (of the wall) 60 cm, was observed, which the local people call bhatti (furnace). Slag pieces were also noticed in this structure. It could be an ancient furnace as a more or less similar example has been discovered at Ujjain (IAR 1957-58:34-36, Pl. XLI B). This will have to be confirmed by future excavations. However, the structure of this furnace appears to be entirely different from that of Rai-Agar near Berinag in the same district. While scraping the vertical section of terrace No. 4 charcoal with slag was encountered at a depth of 50 cm.

As has been discussed above, the plough zone soil is coarse grey, while beneath it there is slight brown soil horizon, but both appear to be clayey and calcareous. Considering the large amount of slag on the fields and no traces of smelting furnace make us think as to why the furnace is not there and how the slag is spreading far and wide. It is natural that a large part of the slag might have rolled down the surface, as the site is located on a steep slope. Perhaps the smelting activity was practised before making those flat terraces for cultivation. It is interesting to note that the above-mentioned cup-mark pit could have been used by the people involved in smelting activities. Perhaps the stone structures including the so-called furnace also belonged to the same people. After they deserted it, the site could have been used for agricultural purposes. A horizontal excavation at the site would throw much light on the smelting technology, as also on its antiquity.

Nearly a kilometre above this site, on the same hill, some digging was noticed which looks like a horizontal shaft enclosed by the natural rock. Only one person can crawl into such a pit. The surrounding soil is rich in ferruginous material. A sample (No. 95) from the site was analyzed at Deccan College, which shows that it contains high grade haematite (Fe_2O_3). It may therefore be suggested that this could have been the nearest mining area of iron ore for them.

In the Asurchula temple, on the peak of the hill, many iron implements like tridents, lamps, have been installed, which is a very common practice in this area. At Agar and Ban-Agar, the Agari people reside along with some Mongoloid Bhotia families. Agaris are known as the traditional iron smiths of this area. The old knowledgeable people of these villages believe that their ancestors were responsible for the aforesaid slag debris. They also tell that at present due to scarcity of ore their livelihood has been shifted from traditional smithy to agro-pastoralism. It is also interesting that they worship Lord Siva in the form of Asura, which might have something to do with the *Asuras* of central India and Bihar. There is also a fort at Lohaghat ascribed to Banasur (Asur-Bani-Pal?).

Lukhani

Lukhani is located about 6 km south of Lohaghat at a height of 1,710 m AMSL, near Medi Dhek village in Pithoragarh district. Perhaps the mountain ridge is named after the ancient mining site. This hill ridge is running south-west-north-east and has a steep slope on either side. Oak (*Quercus incana*), deodar (*Cedrus deodara*) and chir (*Pinus roxburghii*) are predominant along with other bushy and thorny plants of this area.

The hill is composed of micaceous slate rock and at places enormous lenses of quartz are also present. The entire Lukhani ridge is full of iron bearing rocks. On the southern slope of the hill, extensive ancient digging activity was observed. At one location, seven large pits look like mining shafts for taking out iron ores. These pits are circular or oblong in shape, ranging from 2 to 7 m in diameter and 1 m to 4 m in depth. Obviously, these pits were dug to reach the iron rich minerals. In the pit or shaft no. 6, the natural rock is exposed on the surface and a 5-cm thick lens of iron ore was noticed. Two samples from the site were analysed at Deccan College, Poona, by XRD method and it was found that both contain high grade (iron hydroxide). This could have been used as an iron ore.

At the foot of the Banasur hill, which is located about 2 km north-west of Lukhani, a streak of dark red rock was found which appears like cinnabar (?). It is possible that both iron and arsenic were extracted from this region. This will be confirmed by chemical analysis.

About half a kilometre east of the mining pits, the hill slope is strewn with iron slag; however, there is no furnace activity visible on the surface but slag is seen in sizable amounts. Though no human artifact was found at the site, near the ancient crossroad (locally known as Budhi), there is a grove of old oaks (*Quercus incana*). At the base of the oldest oak tree, there are iron implements consisting of a pair of tongs, a trident and a lamp installed in a makeshift shrine, which is dedicated to a village deity. All over this region there is a practice of installing such iron implements in village shrines or even domestic shrines. They are supposed to be dedicated to Betals.

Uleni

Uleni village is located about 8 km north-west of Dwarahat at the base of Dunagiri mountain at a height of 1,200 m AMSL, on the Dwarahat Chaukhutiya road of Ranikhet tehsil in Almora district. A small rivulet flows down to Chaukhutiya to join the Western Ramganga; on the right bank of this rivulet the village of Uleni and its agricultural terraces are located. On these terraces a large heap of iron slag was found. Though traces of any kind of furnace could not be found on the surface, there must have been some furnaces as the large amount of slag suggests. It seems that people might have dug out the furnaces to level their fields. The area is rich in ferruginous material and occasionally huge boulders containing iron ore can be seen in the seasonal Uleni channel. Some PGW sites have also been reported and excavated in the Western Ramganga valley (Nautiyal *et al.* 1978-79, and pers. comm.).

The slag at Uleni was not only found on the agricultural fields but also in a rock-shelter which was located close to the site. A charcoal sample from the site was ^{14}C dated to the early I millennium BC (PRL-1648 2770 $\pm$ 90 BP. Its calibrated date range is 1022 to 826 BC). The ore has to be confirmed by chemical test.

This area is also known as Tamakhani (mine of copper), which suggests that probably in ancient times metallurgy was practised in this area. The slag at Uleni was not only found on

the agricultural fields but also in a rock-shelter which was located close to the site.

Lob

The site is located about 16 km south of Bageshwar in Almora district. The east-west running ridge, on which the Lob village is situated, consists of rich ferruginous soil in an area about 100 sq m. Slag was noticed on the agricultural fields and around the village. A large amount of compact material was found scattered on the ridge as well as on the fields. Though no mining shafts could be identified as the area is under a quarry (of the villagers) for red soil, which they use in their houses. A sample of the aforesaid heavy compact material was analyzed at Deccan College by XRD method, it turned out to be good quality iron ore, *i.e.*, goethite. In the entire Kharahi patti this area is well known for ancient iron smelting and mining. No furnace could be located at the site.

Besides the above discussed sites, there are many other places where, in the course of our exploration, slag was found in small quantities such as at Narayankali, Dwarahat, Baijnath, Chaukhutiya, Bhilkot, Khirmande in Almora district and Channa in Pithoragarh district. Mangal-lekh and Dhyaniarau in Nainital district are also known for iron smelting and mining in Kumaun (Atkinson 1980: 259-76; Vaishnav 1977: 7). Like Kumaun, there are several well known copper mines viz., Dhanpur, Dhobri, Pokhari, Chaunattiya, Nota, Thala Kharna and Danda, in Garhwal, which were mined during the British rule (Atkinson 1989: 282-86).

Copper

Copper pyrite also occurs near Ganai and Phadyali in Patti Athgaon at Bujul and Rathayat in patti Gangoli. There were small mines at Chinkakali, Beler, Sor and at Kemakhet on the east bank of the Ladhiya river in Kali Kumaun.

Ancient sites bearing place-names like Tamakhan, Tamadhauni, Tamadhaun, Agar, Lukhani, Khan-garh (*Khano-ki-garh* = rivulet of mines) suggest a remote antiquity of copper mining in Uttarakhand, which is also supported by the discovery of large scale copper objects including an approximately 22 feet high brass (?) trident with a girth measuring over 60 cm, datable to 6th century AD (Joshi 1987a: 711, 716). Cunningham (1871: 335) also refers to the mining of copper in this hilly tract.

The British started working in Kumaun to exploit copper, iron and other minerals as early as AD 1815. They at first established themselves at Khurpatal, Nainital district and a building was constructed at Kaladhungi to manage the work properly. In 1862, the North Indian Kumaun Iron Company was established. This company started working at Dehchauri, Ramgarh and Khurpatal on the southern fringes of Kumaun in the Lower or Lesser Himalaya in 1862, 1863, 1864 and 1865 respectively. According to the villagers, by 1884 the British government restricted the mining activity in Kharahi patti. However, the people claim that before 1884 they used to pay rupees 4 as tax to the government. In 1942-43 a group of people agitated and urged the government to withdraw the ban imposed on mining in the Kharahi patti. During 1952-56 the Khan-garh area was explored for the existence of copper ore by the Indian government.

The following table (Table 8.2) contains the value of metal, in terms of rupees, that was produced in the last century under the British rule in Kumaun (Table after Atkinson 1989: 275).

Table 8.2 indicates that perhaps mining was one of the important sources of income of the British rulers in Kumaun, in which traditional smithy and mining techniques were employed.

TRADITIONAL TECHNOLOGY

To collect the ore, people used to hang a large bag on their back by tying its corners around the shoulders. A gallery or passage was cut in the face of the hill wherever the ore was found. These galleries are more like the burrows, than like shafts. The sections were always small in

Table 8.2 Copper and Iron production in the last century in Kumaun

Year	Copper (in Rs.)	Iron (in Rs.)
1848-49	2,274	100
1853-54	1,751	48
1858-59	1,532	—
1863-64	870	120
1868-69	929	67
1872-73	1,429	30
Total	8,785.00	365.00

those parts where hardness of the rocks made it difficult to cut a working passage. Atkinson (1989: 267) has also mentioned that "...the passages are scarcely sufficient to admit a person in a creeping posture". According to the Tamta and Agari people of Kharahi, most mining was done in a creeping posture. And while working in such shafts one companion was always used to guard the entrance.

As noted in chapter 2, the Bankot copper anthropomorphs contain 98% copper, 1.22% iron, and a minor impurity of arsenic according to Pant (1991: 41). After examining these artifacts it appears that they were made in an open, single mould, probably made of stone as their measurements show some uniformity also in the finishing as well. Their obverse side shows nodules and gas holes, which suggest that they were made in an open mould, without green poling, and left unfinished. Since there is no copper mine at Bankot, it may be suggested that these anthropomorphs were either manufactured at Kharahi or Rai-Agar and they were being sent to other places for their functional use, but on the way accidentally or purposefully they were buried. The so-called Bankot anthropomorphs could simply be copper ingots as their weights suggest. They are either in the range of 3.4 ± 0.1 or 2.4 ± 0.1 kg.

Traditionally, to smelt the ore, it is ground to powder and then mixed with fresh cowdung. Finally it is dried up to take into the furnace or in a big handi like pot, which is made from locally available brown clayey soil and mixing it with the powdered form of quartz or limestone and *bafila* grass. While smelting the ore, the pot is covered with ash. The fuel, which they use, is known as *baget* or *buget*, which is the bark of *Pinus roxburghii*.

The tuyere (*nala*) is also made of locally available brown clayey soil and quartzite or limestone powder. It generally is 30 to 40 cm long, 8 to 10 cm thick, and the diameter is 10 to 15 cm, narrowing at one end. It is made by grinding magnesite stone mixed with clay. They use simple sun dried tuyeres. Similarly, they make small D-shaped crucibles to melt the ore. For fuel they use the bark of *Pinus roxburghii*, available in plenty everywhere in the forest. They keep ore in the crucible by covering it all around with ash and finally with the pieces of the barks of *Pinus roxburghii* so that the molten metal does not stick to the crucible. This process is repeated again and again to get a purer variety of metal.

The mining activity does not survive any more; it is probably because of the scarcity of ore and lack of financial support. At present nearly 400 Tamta families in Kharahi patti of Almora are involved in copper smithy. Now, they buy copper sheets from the market and produce a variety of utensils using their traditional skills. Since long, their main market has been restricted to some particular localities in Kumaun, e.g., Bageshwar, Jauljibi, Almora, Thal, Devidhura. On the occasion of annual fairs, the coppersmiths of Kharahi and Almora, the iron smiths of Lohaghat and other places of Kumaun, come to these places with their utensils and other productions to meet the demand of the Kumaunis. It is also worth noticing that until 1962, the utensils were exported to Tibet and Nepal, as the smiths claim. Even now, at Jauljibi in Pithoragarh district, a large number of Nepalese come to buy the copper utensils in the month of November, when the fair is held.

The ancient Indian iron smiths exploited the locally available ore and fuel resources. They roasted the ore before smelting; the ore was probably crushed into small pieces. Mixed together with charcoal, it was then fed into small clay-lined crucible-shaped shafts of the furnace; excess fuel was heaped to conserve the reducing condition within. The small bloom that separated out was removed from the furnace, heated to redness in an open hearth, and forged on an anvil in front of the hearth. In the forging process, the adhering slag separated out and simultaneously the surface of the metal was carburised and case-hardened. The bloom was beaten into a thin strip of metal and these strips were later forge-welded together to make a thick mass of iron which was further forged into a suitable object (Hegde 1973: 421).

ETHNOGRAPHIC EVIDENCE

The iron metallurgical tradition in Kumaun is very old and part of the folklore. Like in Bihar and central India, in Kumaun also folklore attributes early iron technology to the *Asuras* (Agrawal & Kharakwal 1998). In Kumaun the folklore tradition is very strong and some of the iron smelting sites are associated with the name Asura, e.g. Asurchula (the hearth of the *Asuras*). It is also interesting to note that an old fort near Lohaghat in Pithoragarh district is attributed by the folklore to Banasur (is it a corrupt form of the Assyrian king's name, Asur-bani-pal?). In fact, some historians have referred to the migration of some early Assyrian tribes to this region in the 8th century BC. The famous local goddess Nanda has been traced to the Assyrian goddess Nana (Vaishnav 1977). These issues have been discussed in detail in our book, *Central Himalayas* (Agrawal & Kharakwal 1998), but we have to admit that so far there is no solid archaeological evidence to prove an Assyrian association. On the other hand, very little systematic work has been carried out in the region so far.

Many sites are associated with the word *lu* (the Kumauni word for iron), e.g. Lukhani, Lohaghat. Some early metal sites are associated with the name Agar, e.g. Rai-Agar, Banagar, Agar and the ironsmith communities even today are called *Agarias*. We are emphasising the folklore tradition because it points to the antiquity of this craft in Kumaun. With the ^{14}C date from Uleni going back to the early I millennium BC (PRL-1648), the antiquity of the folk tradition gains support. From this area we have also collected iron slag which has been analysed and found to be mainly iron silicate, with no traces of copper. We thus find that folklore, historical tradition, the ^{14}C dates and XRD analyses taken together provide the circumstantial evidence that Kumauni iron and iron ores could have been used by the PGW people (Agrawal & Kharakwal 1998).

It is obvious that this whole region of Lohaghat must have been an important centre for

iron mining and smelting activity. The names of Lohaghat for the town, Lohawati for the river and Lukhani for the mining site, all point towards the same direction (*lu*=iron in Kumauni). Iron bearing outcrops are common all over this area. A terracotta cake containing iron slag was found in Banasur fort. It is said that the fort was built by a *rakshasa*=*daitya*=*Asur* king, Banasur.

We begin our discussion with two important and relevant excavations to set the stage for the Kumauni finds. The first is the excavations at Saradkel, an "Asura" site and the second at Naikund (Vidarbha) which throws light on the megalithic iron technology.

The ancient Asura of Bihar and central India are associated with iron technology, so also in Kumaun. In Kumaun, an early iron smelting site is known as Asurchula (hearth of the Asur) and an early alien king Banasur (Asur-Bani-Pal ?) is associated with the early iron sites of Lohaghat area.

The migrations of the Asur tribes and the antiquity of their iron technology may prove a very rewarding study. Below, a brief account of the excavation at Saradkel, an Asura site of Bihar, is given, for possible connections between the two Asur traditions as both were associated with the early iron technology.

Asuras in Bihar

Excavation at Saradkel: An excavation was carried out by the Archaeological Survey under the supervision of S.C. Ray at Saradkel in Ranchi district, Bihar, with a view to finding out the real nature and content of the culture represented by the Asura sites and to determine their chronological position in relation to the other known cultures of northern India (IAR 1964-65: 6).

Excavation revealed two occupational periods, belonging essentially to the same culture. Although no building remains of Period I were unearthed in the limited area under excavation, the occurrence of baked bricks in the strata belonging to this period clearly suggested the use of bricks. A number of pits were encountered, which had charcoal, iron slag and sand; they appear to be iron smelting furnaces. Period II was marked by intensive building activity. A massive defence wall consisting of baked bricks (41 x 26 x 7 cm) was raised along the periphery of the mound in alignment with the contours of the river, apparently to protect the settlement as much from the human onslaughts as from the ravages of floods. The floors were often made of brickbats set in clay base and solidly rammed; floors of intact bricks were also present at some places. In one of the rooms was found a stone anvil which might have been used for beating iron slag.

The pottery was mostly wheel made and characterised by a coarse fabric, thick in section and of terracotta-red colour. A few examples of grey and black-and-red fabrics were also noticed. The shapes represented are jars, bowls and vases. The assemblage of such typical forms as the ledged lid, flat-based bowl, sprinklers, combined with incised decorated designs strongly suggest a Kusana association.

Among other finds, iron objects of diverse utility and shapes deserve special mention. These include arrow-heads, axes with double or single cutting edges, chisels, nails, ploughshares, caltrops, door-hinges, rings and knives. The astonishingly large number of iron objects along with iron slag would indicate that iron industry played an important part in the economy of this culture. Some copper objects were also encountered in this excavation, *e.g.* hooks and rods. Besides these were found some clay sealings; copper coins (possibly prepared from moulds), bearing symbols similar to the ones usually met with on punch-marked coins; terracotta hop-scotches; terracotta

human and animal figurines; beads of chalcedony, agate and carnelian; and a two-legged saddle quern.

The excavation at Saradkel, like the one carried out at Kunila about two decades back, demonstrates that the culture represented by these so-called Asura sites was an iron using one. Brass objects have been discovered in Asur graves in Chhotanagpur but the exact dating of these objects has not been possible. The Asura culture flourished for a limited period in the early centuries of the Christian era and shows neither any signs of genesis nor decay.

The present day Asuras of central India believe in Sing Donga and Marang Bonga. They celebrate mainly the Sohraj, Sarhul, Phagua, Nawakhani, Kathedi and Sarhi Kutasi festivals. The Sarhi Kutasi festival is observed for the prosperity of their iron smelting industry in which a chicken is sacrificed. They also worship their ancestors. They believe in witchcraft, for which they consult Sokha. The Asuras have now become settled agriculturists and many among them have also embraced Christianity; there are also Jat Asuras (Roy 1926).

As there is circumstantial evidence from Kumaun of the association of the cist burials with early iron, we present a brief summary of the megalithic iron technology of the Vidarbha region, the only site in India where megalithic iron technology is well documented.

On the basis of the circumstantial evidence discussed above, we would like to associate the advent of iron technology in Kumaun with the Khasas, a pre-Vedic Indo-Aryan group. Khasas/Khasias still have a strong presence in Kumaun.

We now have dates also for cist burials from Kumaun (Agrawal *et al.* 1995). The date of cist burials and their typology and ceramics relate them to the Swat valley Gandhar Grave culture (Dani 1967) sites. Stacul (1987) has compared some of the Swat burial complexes with those of Kashmir. From Malari (Garhwal), crouched burial, comparable to Burzahom (Kashmir), has been reported. The main common tool type is the rectangular stone sickle. Linguists (Sankrityayana 1958; Vaishnava 1977) have found affinities between the words Khash, Kasha, Kassite, Kashmir, Kashgar, etc.; and the warrior class of Kumaun is still called *Khas* or *Khasia*. They are supposed to be pre-Vedic Indo-Europeans. If these linguistic equations are right, some of these burial complexes may belong to early Indo-European migrations into the western and central Himalayan regions. It may be mentioned here that Rahul Sankrityayana (1958) and other early writers have traced the Khasa people of Kumaun back to the Kassites of Mesopotamia. The people of Kashmir, Kasgar, etc. are all supposed to be related to the Khasas. These were the tribes who preceded the Vedic Aryans and were looked down upon by the latter.

The Khasas, who were perhaps of Central Asian origin, came to India through Northwest, like the Sakas and the Kusanas. At the time of their movement they might have been scattered almost all over the hilly regions of northern India, *i.e.*, Kashgar, Kashmir, Kangra, Kumaun, Kulu, Nepal, even up to Tibet. Though in strength and numbers they might have been stronger than other groups, but they were probably only a nomadic-pastoral tribe. In the course of time, the social peculiarities (Joshi 1929) of the Khasas were more or less dissolved in the larger society of the hills. Now the role of the Caucasoids in spreading iron technology up to China is being recognised. Could the same people may have been responsible for both PG ware and iron in the Central Ganga valley. Could they have been related to the Khasas?

An Zhimin (in Pigott 1996:90) states that metal and its technology could have travelled along the Silk Road and that the technology could have developed in the Qijia culture (2000-1600 BC) of north-western China, which was well ahead of the central plains in its use of copper/bronze. This could also apply to iron technology. With the discovery of the cemeteries in Xinjiang

province that contained more than 100 mummified individuals who were clearly Caucasian (Mair 1995), datable to 2000-1000 BC, and with the presence of iron in west China in 10th century BC, the possibility of a Eurasian origin cannot be ruled out.

Probably for the large scale clearance of forests in the Ganga Doab and needs of the urbanisation, the limited iron resources of Kumaun and difficulty of logistics eventually led to the exploitation of river sands rich in magnetite (Tripathi and Mishra 1977).

CONCLUSION

The parallels in grave architecture and ceramics between the Swat valley and the Kumauni cists are striking indeed. We have shown that the Swat valley (Tusa 1981; Stacul 1987) has yielded remains of iron and grey ware using cultures with remarkable similarity with the Kumauni cists (Agrawal *et al.* 1995). P.G. Ware sites at Thapli and Purola are known from Garhwal. Recent excavations on the Western Ram Ganga terraces by the Garhwal University have yielded evidence of Swat-like graves (Vinod Nautiyal pers. comm.) and a proto-P.G. ware type of pottery. And the Uleni date going back to early first millennium BC thus make it possible that the Central Ganga area could have derived its iron from Kumaun (Agrawal and Kharakwal, chapter 4, 1998).

Thus the evidence, only suggestive so far, tends to link up the Swat valley (Pirak), Central Himalayan iron metallurgy sites, cist burials, Khasa tribes, the Chinese Caucasoid connections, early ^{14}C dates and ancient iron smelting tradition into a consistent pattern which indicates Kumaun to be the probable source of early iron for northern India.

On the other hand, the circumstantial evidence - it is no more than that at this stage of research - does raise strong possibilities of a relationship between the Central Ganga Copper Hoard Group and the Austro-Asiatic language speaking people. The composition of the Central Ganga Copper Hoard artefacts, the Munda and Mon Khmer residue in the Kumauni dialects, the finds of Copper Hoards in Kumaun, the Kumauni copper minerals with arsenic, early dates of metallurgy in Southeast Asia and the new evidence of movements along the Himalayan corridor, seem to fit into an internally consistent framework of a relationship between early Southeast Asian metallurgy, Central Himalayas and the Copper Hoards. If nothing else, the hypothesis needs to be verified on an interdisciplinary basis.

We thus see the possibility of the Central Himalayas having played a crucial role in the development and spread of both copper and iron technologies in northern India as also as a source of supply of copper and iron in the I-III millennia BC. From what I have argued above, it seems that the Central Himalayas may not have been closed *cul-de-sacs* but involved in the dynamics of technological diffusion.

For long, perhaps due to the British influence, we looked only towards West Asia for prehistoric contacts - real or imagined. Recent years have seen commendable and competent interdisciplinary research in Southeast Asia. I think now the excitement lies in the Himalayan corridors and their prehistoric relationship with South China and Southeast Asia. The Central Himalayas, in recent years, have produced some new evidence. The North-east still remains *terra incognita*. It is time we explored the Himalayan corridors and looked East. This will require a paradigm shift in our archaeological thinking - no less.

Having indicated the possible links between Central Himalayas and Southeast Asia, in the next chapter we will discuss the evidence from Southeast Asia.

CHAPTER 9

SOUTHEAST ASIAN ARCHAEO-METALLURGY

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INTRODUCTION

The recent research in Southeast Asia both by the teams from Dunedin and Philadelphia, besides the Thai prehistorians, has forced us to abandon the earlier concepts of Thailand being a backwater and metallurgy beginning there pretty late. Both linguistic (Blust 1996; Reid 1988) and archaeological research (Maddin 1986; Higham 1996; Bayard 1996, in press; Pigott 1985; White 1997) has shown that agriculture and metallurgy could go back to 6th millennium and 2-3rd millennium BC there. As I have argued below, this raises the possibility of technological diffusion through the Himalayan corridors to Central Himalayas and from there to north India (Agrawal 1999a). We have tried to give a glimpse of the Southeast Asian archaeometallurgy as we feel that it is equally relevant to South Asia, as West Asia has been considered so far.

Before discussing the relevance of Southeast Asia to Indian archaeology, we explore below the possibility of the use of the Himalayan corridors for Southeast Asian contacts.

In the dynamics of technological evolution in India, the Himalayas are ignored as isolated *cul-de-sac*. Recent evidence, however, seems to indicate that this region may have played a more crucial role in the development of both copper and iron technologies. Below we discuss the possible role of the Central Himalayas (the present hilly districts of Garhwal and Kumaun divisions of Uttar Pradesh [UP] in northern India) in the development of both early copper and iron technologies.

As mentioned earlier, the possibility of a link between Copper Hoards and Kumauni sources

of copper minerals becomes stronger as at Bankot, 8 lugged type anthropomorphs were found in a stone quarry. Bankot village (long. 79°52'E; lat. 29°45'N) in Pithoragarh district is situated about 13 km northwest of Pithoragarh town. Also, in the foothills (at Haldwani) a typical anthropomorph turned up at a scrap dealer's shop the source of which could only be Kumaun (Joshi 1995-96: 23-31). Thus circumstantial evidence connects the Central Ganga group of Copper Hoards with Kumaun.

LINGUISTIC DATA

Grierson (1967-68) in his linguistic survey of the Himalayas had identified some residue of Mon-Khmer words in the Kumauni dialects. Mon-Khmer is part of the Austro-Asiatic language group (Bayard 1996). With the new ¹⁴C AMS dates from Thailand, the copper metallurgy there can be pushed back to II-III millennia BC. White (1997) reports, "The earliest evidence of bronze at Ban Chiang appears by Early Period II/III in both burial and non-burial contexts. The calibrated results... indicate an early II millennium BC date for this part of the sequence". White further says, "The 3 KUM dating and pollen evidence is broadly consistent with Blust's (1996) linguistic arguments for the expansion of rice-cultivating, Mon Khmer speaking societies down the Mekong from south-western China beginning by the late 6th millennium BC". Higham, however, thinks that KUM dates are just burning episodes in the Lake Kumpahawapi pollen cores and have no necessary relationship with agriculture. He says that the earliest date for agriculture in Southeast Asia is about 2000-2300 BC from Non Pa Wai, Ban Kao, southern China. Higham (pers. comm.) has pointed out that "Non Nok Tha is a cemetery dated to the period 1500-1000 BC". This late date however is not acceptable to others. The dates quoted by White from 3 KUM come from a sediment core. The evidence is consistent with land clearance in the early 5th millennium BC. Such a date seems to accord well with the linguistic argument of Blust (1996). Our experience from the Rajasthan lakes has also been similar: the advent of *Cerealia* type pollen is accompanied (c.7000 BP) by finely comminuted charcoal, which has been interpreted as clearance for agriculture (Singh *et al.* 1990: 351-58). Higham seems to conflate the expansion of the Austro-Asiatic language family with the spread of a specific type of pottery and arrives at the date of 2000-3000 BC as mentioned above. Basically the difference between the positions of White and Higham lies in the estimation of the gap between the advent of agriculture and metallurgy. White argues for a 6th millennium BC beginning of agriculture accompanied by the expansion of the Mon Khmer family of languages, as argued by Blust (1996), and a substantial time gap between the advent of agriculture and metallurgy. Higham, on the other hand, thinks that this gap could be only a few hundred years.

Unfortunately in India, the Northeast is still archaeologically a *terra incognita*. It will be interesting to define the gap between the advent of agriculture and copper metallurgy through the Himalayan corridor. The movement of Munda speaking people along the Himalayan corridor, however, is generally agreed upon.

Now let us see how this evidence is relevant to the Central Himalayas. In Kumaun, the *shilphars*, earlier called Doms, are supposed to be Kols, speakers of Munda dialects (see also chapter 8) (Sharma 1988). Munda and Mon Khmer dialects are two branches of the Austro-Asiatic family. There are many Austro-Asiatic aboriginal languages still spoken in Thailand (Bayard pers. comm.; Bayard 1996). Elsewhere we have discussed (Agrawal & Kharakwal, 1998) that the Kols are said to be the first ethnic group of Kumaun which had descended from the Munda speaking group, which is related to the Austro-Asiatic sub-groups (Majumdar and Pushalkar 1952: 565).

They represent the aborigines of Kumaun. Doms (*shilpkars*) are perhaps the modern representatives of the Kols (Atkinson 1980-81: 370), who today occupy the lowest rung in the hierarchical status in Kumauni society and are now included among the Scheduled Castes. They also claim to have been in Kumaun before either the Khasiya or the immigrants from the plains arrived. The Doms are the traditional smiths in Kumaun.

Higham (1996) discusses the relationship between the Austro-Asiatic and Austronesian languages and whether they belong to a common ancestral Austric phylum and its implications for archaeology. In view of the recent work by Reid (1993, in Higham 1996) and Blust (1993, in Higham 1996), Higham tends to agree with the Austric hypothesis as it would require only one Neolithic expansion and spread of rice cultivation which, according to him, is better supported by archaeological evidence. He describes the Southeast Asian rivers as being like spokes in a wheel, "with the hub in the eastern foothills of the Himalayas.... In a westward direction, ancestors of the Munda moved, perhaps down the Brahmaputra into eastern India" (Higham 1996: 115). Obviously, the movement did not stop there but went further westward to the Central Himalayas. This type of Southeast and westward movements probably explain better the expansion first of the rice cultivation and later on of metallurgy.

Synthesising the archaeo-linguistic evidence Bayard (1996) agrees, "It is very tempting to correlate this with the westward expansion, under the stimulus of agriculture, of Austro-Asiatic (AA) language from Nanhailand through Vietnam, Laos, Cambodia and Thailand to Burma and ultimately eastern India. Linguists have reconstructed a number of terms related to agriculture in proto-Munda, and some of these (husked rice, rice-husking pestle) appear to go back to proto-AA as well. It has been generally agreed for some time now that the prehistoric and early historic inhabitants of Thailand and Burma spoke languages in the Mon-Khmer branch of AA (Bayard 1979: 270). Such an expansion would account neatly - in a general sense for the distribution of the AA languages".

Bayard further says, "Based on morphological evidence such as that presented by Reid (1988: 31-32, in Bayard 1996), Blust is convinced that Schmidt's Austric hypothesis is correct and postulates an Austric homeland in the eastern Himalayan foothills, in the area of the converging valleys of the Salween, Mekong, and Yangzi rivers. From this homeland, one group of rice cultivating people moved down into the middle Yangzi valley to give rise to the AT superfamily of languages ca. 6500-6000 BC. Somewhat later the now-proto-AA speakers remaining in the homeland began to move down the valleys of the Salween and Mekong (proto-Mon-Khmer), with pre-Munda speakers moving westward down the Brahmaputra...." The ethnographic evidence that in Kumaun (unlike for other cereal crops) rice sowing is accompanied by elaborate rituals, may indicate its remote beginnings.

I admit that considerable miscegenation has been going on in the Central Himalayas for several millennia now and the concept of race is now defunct (Kennedy 1995). Yet in the relative isolation (compared to the Ganga Doab) of Central Himalayas one can still observe that the Brahmins and Kshatriyas have sharp features and fair complexion. The Bhotiyas and the descendants of the Kiratas bear unmistakable Mongoloid features. The Doms, who practise blacksmith as a traditional craft, are typically of short stature, dark complexioned and answer to Austro-Asiatic features.

The circumstantial evidence - it is no more than that at this stage of research - does raise strong possibilities of a relationship between the Central Ganga Copper Hoard Group and the Austro-Asiatic language speaking people. The composition of the Central Ganga Copper Hoard

artefacts, the Munda and Mon Khmer residue in the Kumauni dialects, the finds of Copper Hoards in Kumaun, the Kumauni copper minerals with arsenic, early dates of metallurgy in Southeast Asia and the new evidence of movements along the Himalayan corridor - seem to fit into an internally consistent framework of a relationship between early Southeast Asian metallurgy, Central Himalayas and the Copper Hoards. If nothing else, the hypothesis needs to be verified on an interdisciplinary basis.

For long, perhaps due to the British influence, we looked only towards West Asia for prehistoric contacts - real or imagined. Recent years have seen commendable and competent interdisciplinary research in Southeast Asia. I think now the excitement lies in the Himalayan corridors and their prehistoric relationship with South China and Southeast Asia. The Central Himalayas, in recent years, have produced some new evidence. It is time we explored the Himalayan corridors and looked East. This will require a paradigm shift in our archaeological thinking - no less. Let us now have a brief look at the archaeometallurgy of Southeast Asia.

COPPER WORKINGS IN THAILAND

Vincent C. Pigott and Surpass Natapintu (1988) report that the copper sulfide ore body at Phu Lon over the millennia weathered to its present gossan capped state. Prehistoric mining activity at the site appears to have been limited to the upper reaches of the ore body, where oxide-carbonate ores of copper, in particular malachite, were deposited in quartz veins disseminated in the iron-rich host rock. A small pocket of charcoal from the otherwise sterile layers of clear sand and mining rubble at Udom's rock yielded a radiocarbon date in the first half of the first millennium BC. As we will see, this date is in general agreement with other dates obtained from the Pottery Flat. Ample charcoal from the Pottery Flat has provided a series of dates. Charcoal from the basal deposit of the ore-crushing stratum, presumably representing some of the initial activity in this locale, was dated to the first half of the second millennium BC, and charcoal from the matrix of the stratum gave a range of dates in the first millennium BC.

In the Khao Wong Prachan valley, Non Pa Wai, or "Rattan Hill," was the first and most important of the three sites investigated. The entire surface of the site is packed with copper smelting debris. This debris is so dense that the site cannot be cultivated. Its soil is distinct from the surroundings because of its presumed high ash and copper content from centuries of pyrotechnological activity.

Though no *in situ* metalworking installations were identified, among the variety of artefacts found were thousands of thick-walled rice-chaff-tempered crucibles fragments. It is our current opinion that such crucibles were used for smelting. As we have no indications that smelting furnaces, as fixed installations, were used in prehistoric Thailand, this suggestion is of particular interest here. The ores from the excavation at Non Pa Wai and from nearby Phu Ka sources consist of the copper silicate chrysocolla and weathered copper sulfide ores. A second significant category of metalworking artefact found at Non Pa Wai is ceramic bivalve moulds, often incised with geometric pattern on their exterior surfaces.

Implement moulds from the Khorat plateau sites are most frequently sandstone, whereas those known from Non Pa Wai and other sites in central Thailand are uniformly ceramic. The most enigmatic finds were the staggering number of ceramic cup and conical moulds. Their function is presumed to be for the casting of small ingots of copper.

Industrialised mass production of copper-base metal and artefacts is suggested by the huge size of the site of Non Pa Wai, the substantial volume of production debris and the standardised

volume of production debris and the standardised nature of the artefacts used in metal working (crucible, moulds, etc.). Moreover, the unprecedented scale of the copper smelting was well beyond local needs. Finally, a sizeable working population created the depth and expanse of the grey ashy matrix that makes up most of this debris over a substantial period.

On completion of the radiocarbon dating for the upper and basal deposits at Non Pa Wi, Pigott thinks that he will be in a position to discuss the duration of occupation and the potential for both cultural and technological continuity at this major site in this Khao Wong Prachan valley in central Thailand.

Nil Kam Haeng site clearly rivals Non Pa Wai in its physical extent and volume of metalworking debris. It appears that large-scale hand crushing of ores and slags occurred in conjunction with copper smelting at Nil Kam Haeng. Smelting slags and crucible fragments were relatively common at the site, whereas cup and conical moulds were not. Based on current understanding this would make some of the occupation at Nil Kam Haeng contemporaneous with that of the under deposit at Non Pa Wai, where the wares are thought to be later first millennium BC in date.

Pigott & Natapintu (1988) emphasise that the substantial scale of copper production at sites documented by the Thailand Archaeometallurgy Project thus far suggests that production was occurring for a far wider universe than the immediate vicinity of the sites themselves. This raises the possibility of some copper coming through the Himalayan corridors. At least during the first millennium BC, if not earlier, copper production was intense, continuing well into the period when iron was readily available, in the later centuries of the first millennium BC (Pigott & Natapintu 1988).

THAI METALLURGY: ITS CHARACTER AND ORIGINS

White places the Thai metallurgy in a wider perspective. It is heartening to note that White has given serious thought to socio-economic processes in trying to interpret her archaeological data from Thailand. We therefore quote her in some detail.

She reports (White 1988: 175-81), "An inquiry of metallurgical development from the viewpoint of an anthropologist might focus on the hows and whys or what archaeologists like to call the 'processes' of metallurgical development. The hows and whys of any expression of metallurgical use, and even non-use, would be examined in the contexts of specific cultures. In other words, the anthropologist might ask, what was the impact of humankind on the history of metals? The majority of identifiable objects recovered are bangles (bracelets, anklets, and rings) of cast bronze usually with no post-casting modification. Socketed implements, the majority of which are adzes of axes, are common. Spear points seem to be less common. Small tanged implements, including small arrow-heads, and small fish-hooks are occasionally found, but these may be under-represented in terms of frequency of recovery because of the bias of the sample for grave goods. With few exceptions, items appear to be cast bronze alloys with some proportion of tin. The edges of the implements, including axes, spear points, and arrow-heads, are likely to show evidence of annealing and working, which suggests that the implements were functional and not just ceremonial replicas. Thus the early iron artefacts imply cultural continuity in terms of what the ancient society considered an appropriate use for metal, despite the appearance of a new and in many ways rather different metal technology....With the appearance of iron, bronze technology did not disappear. Bronze bangles continue in the Middle Period and Late Period....There exists little indisputable evidence, such as trade items, to prove that Southeast

Asians were receiving cultural contact from China or the Near East during the fourth, third, or early second millennium BC....What is the best working assumption for the relationships among the cultures of Asia during the third millennium BC? There is mounting indirect evidence - linguistic, botanical, and zoological - that Asian people interacted during this time period....I would argue that the best working assumption for Southeast Asia during the third millennium BC is that the region was not totally cut off from the rest of Asia but interacted at some level, perhaps sporadically, minimally, or indirectly, with other societies on the continent....In arguing that Southeast Asian metallurgical province is an example of indigenous innovation, one can point to numerous differences between the metallurgical traditions found in Southeast Asia and in other areas of early metallurgy. Only a few differences will be mentioned. In terms of manufacturing techniques, lost wax does not appear in northern China until the sixth century BC, and hammering and annealing are extremely rare in early Chinese bronze implements. Bangles, which are so characteristic of Northeast Thailand, are virtually non-existent in second millennium China. Of course, the bronze vessels and their piece mould method of manufacture are absent in second millennium Southeast Asia. Socketed axes are common in Southeast Asia, whereas tanged implements are common in northern China....The typological range would also seem to be appropriate for a village-based society. It is the appropriate selection and development of techniques and artefact types over time that makes the Southeast Asian metallurgical province an example of indigenous innovation....I propose that prehistoric Southeast Asian metallurgy was not a false start but rather an alternative pathway....The Southeast Asian metallurgical province shows among other things that complex social structure involving slave or highly organised coerced labour is not necessary to the systematic exploitation of metals. Nor does the regular exploitation of metals necessarily lead in rapid order to greater social complexity or militarization. And most likely, Southeast Asia is not the only case where humankind had an impact on the development of metallurgy”.

About the mode of copper production in the prehistory of Thailand, White & Pigott (1996) think that the evidence supports a community-based model for production organisation from 2000-300 BC. This community-based production showed intensification resulting in a region of specialised production communities at least by the early first millennium BC prior to any evidence for the development of political centralisation. Current evidence suggests that community-based specialisation continued into the period of state formation, and indeed, continues to the present.

“The implications of a strong economic basis in community-based specialisation as characterising a pre-state economy has not yet been addressed in theories of the development of social complexity. The Thai data indicate that even the presence of industrial levels of activity need not correlate with over-arching production controls or pronounced levels of social complexity among the producers.... Philip de Barros (1988) has identified a possibly analogous context in terms of iron production among the Bassar people in northern Togo, West Africa. From the late first millennium AD down to the 19th century, de Barros (1988: 91) has argued that the success of the industry led to ‘higher population densities, larger and more stable communities, a more aggregated craft specialisation and trade.’ Nevertheless, it did not necessarily result in a significant increase in the degree of political centralisation.

“At the very least, strong development of specialised communities and decentralised exchange of their products prior to political centralisation would create an unlikely environment for elite to try to control as a means to accumulate power. Controlling such an economy would seem to require considerable coercive force and great investment in administrative apparatus to bring

production and distribution under regulation. There is no evidence among the early states in the region for this type of investment. Indeed Brumfiel and Earle (1987: 1) have argued that cases of social complexity originating through commercial development must be relatively few. The Southeast Asia data indicate the wisdom in separating the concept of social complexity from the concept of political centralisation. The pre-state economy in the core Southeast Asia region does seem to have developed specialisation and interregional exchange, but the evidence does not support that this production and exchange activity was the basis for political centralisation. On the other hand, society seems to have become more differentiated and complex, but not necessarily along rigidly hierarchical lines. Instead White (1995a) has proposed that a heterarchical model of social complexity be applied to this region, in which lateral differentiation and flexible hierarchy were core social processes. Economic specialisation and interregional exchange served to integrate that differentiated society horizontally.

"Undoubtedly the trajectory to state formation in a region whose pre-state context is characterised by developed community-based production systems, decentralised distribution and social heterarchy will have characteristics and developments that differ from regions with clear evidence for development of rigid hierarchies and elite controls over economic sectors. Sure enough, the historians tell us of the extraordinary flexibility in leadership generation, the lack of standardisation in such area as valuation concepts and the core process of localisation repeatedly evident in the incorporation and transformation of ideas, concepts and practices. The prehistoric record is beginning to reveal that roots of these very processes extend back for over 2000 years prior to the establishment of states" (White & Pigott 1996: 170).

Brumfiel (1995: 125-31) commenting on White's views says, "And so we return to the question posed by White: is heterarchy a form of social complexity? Certainly, heterarchy creates complexity in the lives of individuals. When production is non-specialised or carried out by part-time specialists, the lives of individuals are far more complex than they are in complex economies. As White and Rogers point out, the multiple activities, exchanges and schedules of individuals in heterarchically organised economies results in more varied and challenging lives for the individuals involved. The maintenance of heterarchical social relationships also involves great complexity for individual actors. Rogers observes that in the Yadkin valley, 'autonomous individuals sustained access [to resources] by maintaining level social relations, forging alliances, intermarrying and practising high mobility'. With these scenarios in mind, Rogers characterises the changes from a heterarchical tribal systems to a hierarchical chiefdom as a 'collapse' involving the homogenization and streamlining.

"However, in the literature on social evolution, complexity is most often defined as a property of systems rather than individuals. For example, Flannery (1972: 409) states that the complexity of a system 'can be measured in terms of its segregation of subsystems and centralisation (the degree of linkage between the various subsystems and the highest order controls)...'. The challenge posed by heterarchy is: can segregation occur in the absence of centralised control? We return again to White's observation that in Southeast Asia, social differentiation, specialised production, craft-production elaboration and wealth variation clearly developed over time while centralised control was absent.

"The coupling of differentiation and hierarchy is so firm in our minds that it takes tremendous intellectual effort to even imagine what differentiation without hierarchy could be. In this effort, archaeological data can help guide our thinking; the data will resist the appearance of order until we have developed the proper heterarchical model to fit the case. To a large extent, the possibility

of complexity without hierarchy is an analytical and empirical question that will require substantial model building and testing in the future. But archaeologists who explore the heterarchical organisation of past societies that were not linked to states, empires, or capitalist world systems may be in an excellent position to give advice to social activists who seek to institute a more egalitarian society in our own complex contemporary world" (Brumfiel 1995: 125-31).

Bayard (1980: 199), however, assumes that bronze working was carried out as a part-time "cottage-industry" occupation by a relatively large segment of the population. No evidence for occupational specialisation, bronze artefacts, crucibles, and moulds tend to occur in the richer graves, but these are otherwise indistinguishable from wealthy graves not containing objects associated with bronze working.

Sasaki (in press) thinks that Bayard's interpretation is acceptable and true for other contemporaneous sites, like Ban Chiang. However, recent discovery of an industrial scale bronze-production site of Non Pa Wai in the Khao Wong (Pigott and Natapintu 1988: 159-60) may affect this "cottage-industry" hypothesis if the site is found to be contemporaneous with Non Nok Tha and Ban Chiang.

It seems that there is agreement among scholars that there is a uniformity and an individuality in the Southeast Asian region which warrants its study as a coherent unit. In this connection Higham makes a valuable comment, "I am not alone in being unable as yet to identify the origins of bronze-working, but do argue that it represents a particularly Southeast Asian technological tradition quite distinct from that centred to the north in China. This, again, is a strong argument for a coherence and unity to our area during prehistory. These bronze objects were only found in a few burials. The mortuary evidence currently available suggests that bronze ornaments and implements, as well as exotic stone and shell jewellery, registered status through display" (Higham 1989: 358).

PROBLEMS OF CHRONOLOGY

Before we discuss the new AMS dates given by White, we quote below in detail the views of Donn Bayard, the veteran excavator of Non Nok Tha (in press) on the chronology and origins of metallurgy in Thailand.

"The source of the Southeast Asian bronze technology described here for Non Nok Tha and now documented at a number of other sites remains one of the most problematic and controversial questions in the region's prehistory. I think that it is fair to say that almost all workers in the field will now accept 1500 BC as a minimum date for its appearance, as agreed at the London Colloquy on Early Southeast Asia in 1973. We can discard with confidence the estimates of 300-800 BC for the beginning of the Southeast Asian "Metal Age" which were current prior to the late 1960s. I know of only two recent authors who seem to imply a post-1000 BC date for the appearance of bronze in the region (Loofs-Wissowa 1983a, b; Nitta 1985). The crucial questions now are when and how bronze appeared.

"Debate on the chronology has waxed furious at times. Briefly, it now seems we can put aside the claims for extremely early (pre-3000 BC) bronze advanced by myself, Solheim, and Higham (*e.g.*, Bayard 1980a, Solheim 1980, Higham 1979: 674-5) on the basis of Gorman's proposed chronology for Ban Chiang (Gorman and Charoenwongsa 1976, 1978); White's revision of the chronology of Ban Chiang now makes it appear that the earliest bronze artefact recovered from the site dates slightly later than 2000 BC (1982, 1986; see also Bayard and Charoenwongsa 1983). Moving in the other direction, Higham's 1983 Wheeler Lecture made a forcefully argued

case for discarding the Non Nok Tha and Ban Chiang chronologies in favour of that from Ban Na Di, and a date in the mid- or earlier Second Millennium for the earliest bronze metallurgy in the area (Higham 1984a: 238). Subsequent productive debate between Higham and the present author has resulted in a fruitful near-agreement; Higham would now date the appearance of bronze at Ban Chiang at "not later than 2000 BC", and place the same date on the end of the Non Nok Tha Early Period (1988: 79). Dates for the appearance of the technology in Vietnam are still very sketchy, and non-existent for Laos and Kampuchea, but it seems fairly safe to say on present evidence that bronze technology developed some time in the latter half of the Third Millennium BC, and was widespread throughout the region prior to 1500 BC.

"One important but sadly inconclusive piece of evidence from Non Nok Tha gives a tantalising suggestion that bronze may have appeared sometime in the first rather than second half of the Third Millennium BC. In 1974, while slowly removing the contents of pot NP-1681 for analysis, Solheim found two nodules of bronze at the very bottom of the pot, under some 15 cm of the soil it contained; the pot is a ringfooted type 2B definitely in 1968 B. 4, provenanced to late EP 1 (it had been dug into earlier EP 1 B. 8); while there is some chance that B. 4 could be early EP 2 in origin, there is little chance it could be any later (it in turn has been dug into by an EP 3 pit). No differences in soil colour or texture suggesting rodent or insect burrows were present in the pot contents, and the fragments (3-4 mm in diameter, and together weighing about 5 g) appeared identical to the many others recovered at the site. There is of course no chance that the bronze was introduced from a bronze-period layer in the course of grave digging, as EP 1 represents the earliest use of the site, and is otherwise ametallic, as is EP 2. The most economical argument would seem to be that the nodules were placed in the pot at the time of the burial. If the material were to prove to be bronze, the implications are very significant, as it is difficult to see on present evidence how EP 1 could date any later than 2500 BC at the latest.

"Unfortunately, we are unable to present any substantive data on this early metal. Solheim recognised the importance of the find immediately, and made plans to have the specimens and a sherd from the pot that contained them hand-carried to the U.S. Mainland for analysis and thermoluminescence dating. The samples were duly delivered to the laboratory by Chet Gorman in the autumn of 1974, but went astray thereafter; all attempts to locate them to date have been unsuccessful. It is tempting to speculate about the first tentative movements of the new and still very rare commodity from an as-yet unknown source along trade networks which were already bringing marine shell and fine-grained stone into the Phu Wiang region at a date probably closer to 3000 BC (or earlier?) than 2500. But sadly, speculation is all it is; hard evidence is lacking. Hopefully further research in the region will supply us with a definitive answer to the dating of early bronze in the region within the next decade or two.

"But equally or more important than dates is the question of how the technology appeared; was it a totally indigenous development, without outside influence, or was it somehow introduced by a form of diffusion from the Huanghe region of Northern China or—further afield—the Indus or Near East?

"It is simply impossible to answer these questions at present, and much of one's beliefs (for such may be a more honest term than "opinions") is dependent on preconceptions of human capacity for innovation. At issue is the admittedly extreme difficulty in establishing the links between pretty rocks, very high heat, and a hitherto undreamed of but very malleable and useful metal. As the noted metallurgist Cyril Smith wrote to me many years ago, metallurgists tend

to be diffusionists and anthropologists independent inventionists. However, Bronson, an anthropological archaeologist well-versed in metallurgy, has recently said he feels that Southeast Asian bronze must have an ultimate origin outside the region, if only because the great gap in time that separates the earliest Middle Eastern experiments with metals to their appearance several millennia later in Southeast Asia "makes it almost certain that diffusion of some sort occurred—perhaps only of general concepts rather than of artefacts or specific technologies" (Bronson 1985: 40). Wertime's 1973 arguments for the necessity of a "polymetallic" phase of experimentation preceding intensive, well developed metallurgy are also cogent ones against a completely indigenous origin in Southeast Asia, where no evidence of an experimental phase has yet been recovered: metallurgy appears as a very uniform technology over a wide area in a relatively short span of time. Others have argued that pyrotechnology was not well enough developed to achieve temperatures high enough for smelting and melting (Higham 1984a: xxx). However, this argument has been weakened by experiments suggesting that temperatures approaching 1000 degrees C. were probably attained in normal firing of pottery (Solheim and Meacham 1979; Vincent in Higham and Kijngam 1984: xxx).

"While the case for totally independent invention is thus a weak one, we must then ask the question 'if introduced, from where?', and this presents almost equal difficulties. I have discussed this question elsewhere (Bayard 1980b [written 1971], 1987), and to my mind a clear, documented source outside the region at the proper date and with a related technology is still lacking. Higham (1984a: 248) has implied a possible source for Southeast Asian bronze in recent finds in Gansu purported to date to the earlier half of the Third Millennium BC. I have questioned the likelihood of any connection (1986-87), and after first-hand examination of the materials Higham now agrees the two traditions are quite distinct (1986-87:144; 1988, in press). Noel Barnard has also informed me that he believes there are no parallels present between the metallurgy of Southeast Asia and that of North China until the late Zhanguo period (*ca.* 300 BC; pers. comm.). More distant connections to the west are at present even more difficult to establish at a date prior to 2000 BC.

"What is needed now is intensive clarification of the relationships between the similar regional technologies of northern, central, and southern Vietnam, Kampuchea, Laos, Northeast Thailand, and the Chao Phraya valley; the location of the ore sources utilized by these technologies is also crucial, and Pigott and his Thai associates (1985) are making significant discoveries in northern and central Thailand. Even more crucial is the need for a comprehensive review of all of the evidence for prehistoric metallurgy available from Fujian south through Guangdong and Guangxi to Yunnan, in order to establish links presently obscured by modern political divisions. However, until convincing evidence of a related technology at an appropriately earlier date appears, either in South China or elsewhere, I will continue to hold the belief (and it is only that!) that the metallurgical technology developed in Mainland Southeast Asia in the centuries preceding 2000 BC was largely an indigenous one, in the sense I used the term in a paper presented in 1971: ...a technology indigenous and independent in all but the very germ of its origin. We will probably never know whether the first very basic steps in metallurgy were independently discovered in the area or introduced from outside ...; the point I wish to emphasise is that the technology was indigenously developed if not discovered. I would agree wholly with [Cyril] Smith (personal communication) that the presence of the inventive aborigine on the one hand or the knowledgeable traveller on the other is by and large a question of faith. (Bayard 1980b: 198-99). Some fifteen years after this was written, White in a review of Southeast Asian metallurgy has also proposed that "we can talk about an indigenous, 'Southeast Asian metallurgical province'. ... Although there

is site-to-site variation, in terms of technology the configuration of the prehistoric metals in Southeast Asia both shows an internal coherence and, taken as a whole, considerable distinctiveness from other major areas of early metallurgy" (1987: 15). As she correctly points out, there is no need to postulate a primary origin elsewhere and diffusion of the complex as a whole into Mainland Southeast Asia simply because the region lacks signs of centralisation or formalised militarism. Despite Higham's 1984 statement that metallurgy must somehow stimulate "concomitant changes in social complexity noted under similar conditions in the Aegean, Near East or Shang China" (1984a: 238; repeated but qualified in Higham 1984b:4, and subsequently rejected in Higham 1986-7: 144), there is no reason to suppose that at least 1,500 or 2,000 years of village-level bronze-casting should in some way have contributed to increased social complexity. Metallurgy is surely better considered one of the servants of society than one of its masters" (Bayard, Nono Nok Tha report in press).

Now let us discuss the new data that White has provided and the serious differences between her's and Higham's chronology. At the Indo-Pacific Prehistory Association Conference in Chiang Mai in January 1994, White (1997) announced that dates from two research programmes were forthcoming that would shed light on the chronology of the Ban Chiang Cultural Tradition. The two University of Pennsylvania related research programmes are: 1, the Thailand Palaeoenvironment Project (TPP), and 2, the Ban Chiang AMS (Accelerator Mass Spectrometre dating Program). Results are now available from both projects. White's note briefly reports on preliminary results relevant to two issues of interest: 1 dating for the settlement of the Sakon Nakhon Basin by agricultural societies (=base of the Ban Chiang Cultural Tradition), and 2 dating for the appearance of bronze at Ban Chiang.

White (1997) says, "Tables 9.1, 9.2, 9.3* present the seven dates from the TPP core '3 KUM' from Lake Kumphawapi in the Sakon Nakhon Basin, which is located about 30 km from Ban Chiang. This 6.18 metre core has provided the first continuous palaeovegetation record for lowland interior Southeast Asia dating from the terminal Pleistocene to the late Holocene. The full presentation of the pollen (Penny, in preparation) and phytolith evidence (Kealhofer and Penny 1996).... suggests anthropogenic landscape modification including burning, possibly since the terminal Pleistocene. The pollen evidence indicates that by about 1 metre from the top of the core a marked peak in carbon fragments coincides with substantial vegetation changes including decline and even temporary disappearance of several arboreal taxa. Such evidence is consistent with anthropogenic land clearance, and its sudden and emphatic appearance in the pollen record strongly suggests colonisation rather than gradual *in situ* development, by cultivating societies. This change falls between the two dates Beta-93027 and Beta-93028 placing the "event" in the 5th millennium BC (cal).

"If this marked change in the palaeoenvironment records signals the base of the Ban Chiang Cultural Tradition, the implications for 5th millennium BC timing are significant. This date is much earlier than archaeologists have previously considered for the appearance of agricultural settlements in this region. The Higham (1996) estimate of mid-third millennium BC for expansion of settled agricultural groups into this regions appears to be young by two millennia. White's (1986), argument for the fourth millennium BC (based on four dates from basal Ban Chiang, and a fifth from basal Ban Tong) appears to be young by one millennium. On the other hand, the 3KUM dating and pollen evidence is broadly consistent with Blust's (1996) linguistic arguments

* Table Nos. have been changed by the author.

for the expansion of rice-cultivating Mon-Khmer speaking societies down the Mekong from south-western China beginning by the late 6th millennium BC.

"Concerning the dating of bronze in the Ban Chiang sequence Tables 9.2 and 9.1 give pertinent results from the pottery program. Previous charcoal based dating has been criticised due to ambiguity of association between the dated sample and cultural contexts (Higham 1996). The dates reported here derive directly from rice tempered burial pottery with impeccable provenience. The carbon from rice temper comes from short-lived plant remains incorporated into clay fabric shortly after harvest during vessel manufacture and deposited into its archaeological context probably within a few years.

Table 9.1: Radiocarbon dates from 3 KUM, Lake Kumphawapi, Thailand (White 1997)

Lab no	Depth(cm)	Calibration (OxCal) 1993 curve 2 sigma
Beta-93027	80-86	4520-4240 BC
Beta-93028	136-141	5140-4830 BC(0.94) 5210-5160 BC(0.06)
Beta-93029	152-157	5430-4950 BC
Beta-93030	255-268	7920-7480 BC
Beta-93031	355-363	7950-7300 BC
Beta-72096	540	8550-7950 BC
Beta-72097	580	12750-12050 BC

Table 9.2: AMS radiocarbon dates from Ban Chiang Early Period burial ceramics (White 1997)

Lab no	Specimen	Phase	Calibration (OxCal1993 curve 2 sigma)
AA-15581	BCES B.56 Pot B 2215	EP Vb	1320-1000 BC(0.95) 1390-1340 BC(0.05)
AA-15582	BCES B.59 Pot A 2318	EP Va	1740-1450 BC
AA-15583	BCES B.63 Pot A 2356	EP III ?	4800-4510 BC
OxA-6069	BCES B.47 Pot B 2161	EP III	3770-3370 BC
AA-12538	BCES B.72 Pot D 2835	EP II/III	1950-1600 BC(0.99) 1560-1530 BC(0.01)
AA-15578	BC B.46 Pot A 1608	EP II c	2050-1500 BC
AA-15579	BC B.47 Pot A 1621	EP IIb	2190-1880 BC

Table 9.3 Ban Chiang: Calibration of stratified Early period AMS dates (White 1997)

EP Vb	superimposed burials	AA-15581 2970 + 60 BP
EP Va	superimposed burials	AA-15582 3320 + 50 BP
EP II/III	superimposed burials	AA-12538 3470 + 70 BP
EP II	superimposed burials	AA-15578 3465 + 100 BP
EP II b	superimposed burials	AA-15579 3655 + 55 BP

"With the exception of two dramatically old dates which cannot be considered archaeological meaningfully (both from Early Period Phase III), five of the determinations are internally consistent both in terms of their relative phase assignment, and in terms of their position within superimposed sequences of graves. The earlier evidence of bronze at Ban Chiang appears by Early Period II/III in both burial and non-burial contexts. The calibrated AMS results, particularly AA-12538, indicate an early 2nd millennium BC date for this part of the sequence.

"This evidence supports White's previous (1986) estimate of the early 2nd millennium BC for the appearance of bronze at Ban Chiang and provides direct evidence of pre-1500 BC cal bronze in Southeast Asia (cf. Higham 1996). This dating is comparable to the current consensus on dating for the appearance of bronze in Central and East Asia. A possible implication raised at this conference was that the early Thai evidence for a developed bronze technology lacking experimental stages may relate to a rapid and broad spread of bronze technology in Asia east of the Urals dating from about 2000 BC or shortly thereafter (White 1997: 103-6). Quite independently from Bayard (1984), White (1982) has proposed a chronological sequence for the site of Ban Chiang, consisting of the Early (3600-1000 BC), Middle (1000-300 BC) and Late (300 BC-AD 200). The division is based on change in mortuary practices and in pottery style and is not related to the evolution of metallurgy. Bronze appears in the archaeological record sometime in the Early Period, and iron in the Middle Period (Stech-Wheeler and Maddin 1988:163, 166). Consequently, Bayard's General Period A corresponds to the Early Period of Ban Chiang before bronze was known, and General Period B to the later half of the Ban Chiang Early Period and the early half of the Middle Period before iron was introduced" (White 1997).

Stech-Wheeler and Maddin (1988: 163) however believe that metal (bronze) first occurred at Ban Chiang around 1700 BC. This proposed date is consistent with the Vietnamese proposition of the earliest bronze for the Second Millennium BC, and White's (1982: 175) idea of 2000 BC for the earliest bronze at Ban Chiang.

The bronze spearhead discovered in the lowest layer of the site was cast as a unit in a bivalve mould with a core inserted during casting to shape the socket. Chemical analysis has revealed that the spearhead contains only 1.3 per cent tin (Stech-Wheeler and Maddin 1976: 38, 41). Because of the 10 to 20 per cent error factor, and since five other bronze objects dated to the Early Period all contain 5.5 to 12.5 per cent tin, Stech-Wheeler and Maddin (1988:165) now believe that the alloying of copper with tin was already known at that time.

It may be noted here that prior to White's proposed chronology, researchers used to rely on a tentative chronology published by Gorman and Charoenwongsa (1976: 17-24) based on change in pottery style and mortuary pattern: Phases I through III for 3600 to 2000 BC; Phase IV for 2000 to 1600 BC; Phase V for 1600 to 700 BC; and Phase IV for up to 250 BC; Phases I through III seem to correspond to White's Early Period; Phases IV and V to the Middle; and Phase V to the Late. The excavators of Ban Chiang, Gorman and Charoenwongsa (1976: 17) originally published the date of 3600 BC for the earliest bronze discovered in the lowest layer, and Stech-Wheeler and Maddin (1976: 41) were at that time in agreement on the date.

Discussing the chronology of Thai metallurgy, Sasaki (in press) says, "Before the discussion of archaeological evidence of early metallurgy in Southeast Asia, it is necessary to clarify the chronology and dates. Bayard (1984:162-63) has proposed the general chronology for the whole of Southeast Asia based on the sequence of dates from Non Nok Tha. There he has distinguished three basic stages from the earliest where metal was absent, through the middle where only bronze was present, to the late where iron became common. He considers the Non Nok Tha sequence

relatively secure internally and through its close ties to other sites in Northeast Thailand" (Bayard 1979: 25, 30; 1980: 191).

According to Bayard (1984:163), the General Period A is characterised by the development of at least semi-sedentary agricultural communities during the period between 3500 and 2500 BC, with noticeable but fairly weak social ranking. The General Period B is distinguished by the appearance of bronze technology (and presumed strengthening of already present trade links) during the period between 2500 and 1800 BC, with an increase in social ranking, but still at a simple-ranked level. The General Period C is represented by the introduction of iron technology and intensive wet rice farming during the middle First Millennium BC, with a more marked increase in ranking. Sasaki considers this general trend acceptable, but we must still be careful with the absolute dates. Although Bayard (1979: 30) claims that 28 out of 36 absolute dates support the presence of early bronze metallurgy at Non Nok Tha, Imamura (1979) believes that the excavators intentionally ignore younger dates. Among these three stages, the present paper focuses on the General Period B when bronze came into use and before iron was known to Southeast Asians. Sasaki thinks that Bayard's date of 1800 BC seems wrong; it should be 800 BC. Otherwise, there would be a gap between the General Periods B and C. It doesn't fit in Higham's (1988: 132) chronology at Ban Na Di, either (Sasaki in press).

As the discussion above shows, the chronological controversies among main workers in Thai archaeology are still serious. The only definitive data that seem to sort out some of these chronological problems are from White (1977) as quoted above.

BAN CHIANG

Spearheads (Fig. 9.2) and other socketed utilitarian items were cast in symmetrical bivalve moulds with a core piece, which is considerably more elaborate than a single mould method. Working and annealing were also practised. Bangles (Fig. 9.5) and bells discovered at Ban Chiang may have been made in the lost-wax technique (Stech-Wheeler and Maddin 1988:165; White 1982: 44). Stech-Wheeler and Maddin (1988: 165) conclude that "the basic technique of copper working seems to have appeared full-blown at Ban Chiang" (see Figs. 9.1-5).

At the site, the excavators have recovered a casting area marked by masses of baked clay and scattered remains of crucibles. The clay crucibles are characterised by a pinched spout and are heavily tempered with whole rice husks to prevent breaking from thermal shocks. No evidence for the smelting of ores has, however, been discovered at Ban Chiang. Since ore sources are not in close proximity to the site, smelting may have taken place near the sources (White 1988:177-78).

Bronze objects discovered at Ban Chiang include both utilitarian and ornamental items. Since the artefacts are primarily from burial contexts, the data set may be skewed. Most of the tools, such as an adze (Fig. 9.1), and spearheads are characterised by a hollow socket for the insertion of a shaft. Some adzes bear no evidence for cold hammering or annealing to harden the edge, which suggests the possibility that they were not used before being buried. While ornamental items in the Early Period are not decorated, those from the Middle Period show surface modifications for decorative purposes, such as the addition of bosses or knobs (White 1982: 40).

NON NOK THA

Donn Bayard has kindly allowed me to quote the following extracts from his unpublished report on Non Nok Tha.

Technology

Bayard reports, "Even when it was the sole stratigraphic witness to what I referred to in a 1971 paper as 'an early indigenous bronze technology' (Bayard 1980b), Non Nok Tha alone suggested the outlines if not the flesh of the manufacturing techniques employed. Bronze was obviously being cast at the site (crucibles, nodules, moulds), although not smelted (no slag present); tools such as axes were being cast in bivalve sandstone moulds, while decorative items like bracelets and rings were in all probability being made by the lost wax process. By 1970 it was apparent from analyses such as Smith's (1973) that leaded bronze was the alloy of choice for at least some of these ornaments as well as some of the weapons.

"Although rather insecurely provenanced specimens of bronze and stone axe moulds had been recovered from much earlier excavations (*e.g.*, Mansuy 1902), the novelty of the stratigraphically secure finds and the startlingly early radiocarbon dates associated with them aroused considerable interest and controversy. While Non Nok Tha stood as the sole evidence for this technology, such controversy was of course understandable and justified; as I said in my 1971 paper, "Given the lack of data and adequately excavated sites in this huge region this [speculation] will doubtless continue to be the case for at least a decade" (1980:204). In fact, the speculation and debate has predictably continued to the present (Loofs-Wissowa 1983a,b; Bayard and Charoenwongsa 1983; Solheim 1983; Higham 1984; Bayard 1987; Higham 1987; etc.).

"Fortunately for the debate, further evidence has been forthcoming from other excavations, both in Northeast Thailand and further afield in Vietnam.

"The 1974-75 Fine Arts Department, University of Pennsylvania excavations at Ban Chiang (Gorman and Charoenwongsa 1976, 1978) provided evidence of similar bronze axes, crucibles, and mould fragments at what seemed to be even earlier (pre-3000 BC) dates than Non Nok Tha. More recently the excavation of Higham and his students at Ban Na Di, near Ban Chiang, has produced very important evidence for early bronze technology in the region (Higham and Kijngam 1984:81-147). Firstly, the carefully collected and provenanced charcoal samples from this site provide quite conclusive evidence for well-developed bronze technology by the middle of the Second Millennium BC. Even more importantly, the site produced not one but several *in situ* bronze casting furnaces from layers dating between 900 and 1 BC. Finally, the large interdisciplinary team recruited by Higham allowed an in-depth examination of artefacts and technology, including even an analysis of the insect wax used in lost-wax casting (Higham and Kijngam 1984:124-26). Further afield, intensive archaeological research in Vietnam over the past 15 years has revealed a large number of parallels with the materials from Non Nok Tha; there are general technological parallels at the northern sites of the Dong Dau and Go Mun cultures, and possible parallels with some of the as yet incompletely reported early Sa Huynh sites in central Vietnam. The most striking parallels are with the site of Doc Chua, northwest of Ho Chi Minh City; many of the numerous axe moulds and axes from this site could as well have been excavated at Non Nok Tha (Ha Van Tan 1980; Murowchick 1986; Higham 1986).

"The technology as evidenced by the totality of this material seems generally quite straightforward. Bronze was traded into the site in metallic form, either as ingots of copper and tin or more probably of the finished alloy itself; as no ingots have been recovered, this remains to be discovered.

"Judging from Selimkhanov's 28 spectrographic analyses of 11 bronze casting spills from Non Nok Tha, there is a possibility that lead was traded in separately and added to the alloy at the time of casting; none of the spillage samples, which ranged from EP 3 to LP 2, had

more than 0.04% of lead.

"The bronze was melted in crucibles made of clay tempered with large quantities of rice chaff and straw, and in the case of the earlier layers at Ban Na Di with grog; chaff temper came to predominate at the latter site only after about 500 BC (Higham and Kijngam 1984:84-91). These crucibles had an average capacity of about 100-200 ml at Non Nok Tha, sufficient to hold about 0.9 to 1.8 kg of molten bronze. However, at least two smaller crucibles were found at the site (one holding only an estimated 20 ml), and both of the crucibles recovered from Ban Na Di were toward the low end of the Non Nok Tha range, holding about 70 to 90 ml by the formulae adopted here.

"Although there were at least two major periods of fairly intensive use of the site for bronze casting as evidenced by abundant casting spillage (MP 5 and LP 2), no clear traces of hearths or furnaces to melt the bronze were discovered. However, we can extrapolate from those discovered at Ban Na Di: the bronze was melted in small, scooped-out furnaces lined with blocks of clay. The layer 7 example described by Higham (1986:5, fig.5) measured about 75 by 60 cm; it had a base of compacted earth and sides of burnt earth and clay, enclosing a hollow some 25 cm deep filled with charcoal. An inlet at one side presumably admitted tuyeres worked by blowpipe or bellows (given the widespread ethnographic distribution of piston bellows—still in use in the area today—the latter is more likely). As the inlet in the Ban Na Di example described is at the top of the furnace, it seems likely that Smith is correct in assuming the crucible was placed in the furnace and fuel (charcoal) then piled on top rather than underneath it (1973:30). Once melting was complete, some sort of relatively heatproof tongs—perhaps of green hardwood or bamboo—was used to remove the crucible for pouring into the (probably preheated) stone moulds.

"The mould blanks which were found at Non Nok Tha—ranging from rough un-split blocks to fragments from split and smoothed halves—hint strongly at the manufacturing process employed: roughing out and splitting of a suitably sized sandstone block; smoothing of inner and outer surfaces; incising and hollowing out the shapes of the item to be cast; and final fine smoothing of the inner surfaces of both halves to ensure a good casting with minimal flashing. Subsequent excavations at Doc Chua in 1976-77 (Dao Lin Con 1977, Nguyen Duy Ty 1977) have produced axe moulds almost identical to those recovered at Non Nok Tha (*e.g.*, see Ty 1977, Fig. 5). More importantly, as Murowchick points out in his summary of the metallurgical finds there, more than 50 moulds in all stages of manufacture have been recovered, illustrating the cutting, chiselling, and polishing of the preliminary stages of manufacture.

"Several of the Doc Chua moulds retain faint traces of yellow clay, while others suggest that a model of the object to be cast was held against the mould and exposed to a smoky fire, staining the outline of the model onto the mould surface. The shape was then chiselled out, a delicate process subject to errors that forced the Doc Chua Mould makers to discard a number of partially finished moulds.

"Finally, the inner surfaces of the mould were carefully polished; a few of the moulds received simple decoration at this stage, usually consisting only of one or two raised ribs running around the body of the axe between socket and blade. Many of the moulds show a variety of incised lines on their outside edges, undoubtedly meant to facilitate the careful alignment of the mould halves prior to pouring the molten bronze (Murowchick 1986:8).

"No traces of clay or smoke outlining were found on the Non Nok Tha moulds, nor was there any sign of incised registration grooves for aligning the halves; nonetheless it is clear that the mould technology employed must have been nearly identical to that at Doc Chua, some

800 km Southeast of Non Nok Tha. Although we have always assumed that the sandstone moulds were employed to cast bronze items directly, Higham has recently suggested that perhaps they were used only in an intermediate stage to cast models of low-melting lead alloy. These latter models would then be used to shape clay models which when fired could better resist the thermal shock of casting than sandstone, which would have been destroyed during casting (Higham and Kijngam 1984:83; Higham 1984b:140); this conclusion was stimulated by the discovery at Ban Na Di of a unique lead-tin alloy casting sprue (Higham and Kijngam 1984:110). However, given the lack of any traces of clay axe mould fragments at Non Nok Tha, Ban Chiang, or other related sites and the obvious signs of heat blackening on many of the Non Nok Tha pieces, their use for casting of lead models only seems unlikely; it would be difficult to explain the bronze corrosion stains on moulds noted above if this were the case. At least one pair of moulds has demonstrably withstood the shock of casting after some 3,000 years of burial; White (1982:fig. 56) illustrates a bronze axe cast in mould pair NP-82, flanked by the moulds themselves. Murowchick also finds this argument unconvincing (1986:8), and Carriveau suggests that the apparent slow cooling of cast axes was accomplished by preheating of stone moulds (1978); it would be difficult to achieve such slow cooling in a clay mould unless it were of considerable thickness. Even Higham and Kijngam conclude that it is still probable that the stone moulds 'were used to cast directly in bronze' (Higham and Kijngam 1984:125).

"There remains the interesting question of the significance, if any, of the differential pattern of heat blackening observed in the socket mouth area of some of the moulds (particularly NP-550, NP-82, NNT-36). This may have resulted from the use of some type of (fired clay?) plug shaped to fit the socket opening and ensure a symmetrical socket in the cast tool. No such patterns are shown on drawings of moulds from Doc Chua and elsewhere, however, and the suggestion remains speculative until such plugs are found".

Casting of bracelets (based on Bayard in press): Five of the D-shaped bracelets were examined by Smith, and Rajpitak analyzed all but two of the 17. Smith arrived at the conclusion that casting in a bivalve mould would have been difficult; lost wax manufacture was a more likely method, although "neither certain nor necessary". If such were the case, Smith offers a very plausible method for their casting: "The D-shaped section may have been formed [in wax] over a pre-formed cylindrical core of clay; then the whole was embedded in clay, the wax melted out, and the metal poured into the space formerly occupied by it". If the cylindrical core were tapered and multiple wax models applied around it, the result could have been a graduated set of different-sized bracelets like these.

Rajpitak's analyses of the bracelets reveal an interesting pattern: the 14 D-shaped ones contain between 8 and 12% tin (mean 10%), and from 0.5 to 1.2% lead (mean 1%); hence it is debatable whether or not the lead was a deliberate addition. However, the single decorated bracelet with circular cross-section which she analyzed contained 8.6% tin and 4.5% lead, resembling NP-553 above (but note that the analysis is based on corrosion product). One of the decorated bracelets was also reported on by Stech-Wheeler and Maddin (1976:43). They also suggest that it was cast as a whole (including decorative motifs) by the lost wax process and rapidly cooled.

The excavations produced additional evidence of *in situ* bronze-casting in the form of several whole crucibles included as offerings in burials, as well as a small number (12) of crucible fragments recovered in layer removal. The relatively scanty finds of fragments in occupational/industrial deposits contrast sharply with site like Ban Na Di, where some 158 crucible fragments were recovered (Higham and Kijngam 1984:84-91). This, as well as the lack of any clear signs of

bronze casting furnaces suggest that bronze working was carried out to a far less intensive degree at Non Nok Tha, although oddly enough very similar numbers of bronze lumps and detritus were recovered from Ban Na Di and Non Nok Tha (approaching 500 in both sites). Unlike Ban Na Di, all crucibles and fragments recovered at Non Nok Tha were tempered with rice chaff and a small amount of sand (possibly a natural inclusion); no examples of the grog-tempered crucibles characteristic of layers 7 and 8 at Ban Na Di (Higham and Kijngam 1984:85-7) were found at Non Nok Tha. Although size and volume estimates are given below for the more complete crucibles, it should be emphasized that the latter are tentative, based as they are on average measurements and the application of the ideal formula for a prolate spheroid ($4/3 E3ab^2$) after wall thickness is subtracted. The total volume is divided by 3 to reflect the sub-hemispherical shape of most of the crucibles; weight of bronze capacity is based on a specific gravity of 8.8 g/ml. These tables clearly show the continuous presence of bronze at the site from the end of the Early Period onward; the frequent finds of bronze lumps and droplets which in most cases may be interpreted as casting spillage also indicate that bronze casting was carried out at the site throughout the Middle and Late Periods. This appears to have been concentrated particularly in MP 5 and LP 2, but MP 3 and LP 1 also feature fairly heavy concentrations of nodules. As with subsequently excavated bronze period sites in the region, the evidence for bronze technology consists of moulds and crucibles as well as the bronze remains themselves.

NON NOK THA BRONZE ARTEFACTS (From Bayard in press)

"The 1966 and 1968 excavations yielded some 79 classifiable bronze artefacts plus another 116 possible fragments of objects and about 340 nodules from casting spillage; the total weight of bronze recovered is about 2.2 kg. When one recalls the richness and quantity of bronze finds of Dian and Dong Son sites—or even those of the Go Mun period in northern Vietnam—the Non Nok Tha finds seem petty by comparison, and indeed Higham has commented on the relative rarity of bronze at sites like Non Nok Tha and Ban Na Di.

"However, at least one archaeologist specialising in the Near East on viewing the Non Nok Tha bronze finds was surprised by the quantity of bronze represented by the few pieces he saw. Given the relative abundance of copper and tin ores in the region as a whole (Charoenwongsa 1978) and the obvious presence of established trade networks in Northeast Thailand well before the first appearance of metal (as evidenced at Non Nok Tha by exotic shell beads, adzes of non-local stone, etc., Bayard 1971, Kennedy 1977), it is not surprising that bronze rapidly became a commodity in this network (Higham 1984a; 1988). As the Non Nok Tha sequence spans the period of transition to bronze technology, the bronze and bronze related artefacts can provide some insight into the nature of the technology, if not its origins. Well over 100 analyses of the Non Nok Tha bronzes have been carried out by a half-dozen different metallurgical specialists (Pittioni 1970, Smith 1973, Stech-Wheeler and Maddin 1976, Carriveau 1978, Selimkhanov 1979, Rajpithak 1983); these included both qualitative and quantitative analyses of most of the bracelets and bracelet fragments, a number of possible object fragments, and lumps interpreted as casting spillage (summaries of quantitative analyses are given in Vol. II). However, only two of the five bronze axes were quantitatively analyzed, as the Thai Department of Fine Arts was reluctant to have the remaining pieces sectioned for sampling.

Axes: "The earliest and probably best-known of the Non Nok Tha finds, this was the only metal artefact recovered from an Early Period context at the site; the only other definitely confirmed finds of bronze in a pre-Middle Period context were two tiny fragments in the pit fill of the

empty grave of EP 3 B. 93, adjoining this burial. The tool was found in a very secure context, among the ribs of B. 90, which is provenanced to EP 3 both by stratigraphy and typology.

"The tool weighs 149.8 g, and is trapezoidal in shape, narrowing from a width of 5.3 cm at the socket to an estimated original width of 4.3 cm at the blade end (the lumpy mass of corrosion which now covers the blade is slightly wider, at 4.6 cm); the total length of the tool is 9.0 cm, and its thickness is 2.2 cm at the socket and 1.1 cm at the corroded blade end. The socket measures 4.6 by 1.7 cm. The shape is thus quite distinct from the later bronze axes and moulds recovered from the site, all of which exhibit widening of the axe from socket to blade. Also distinctive is the asymmetry present along the long axis of the tool: although evenly curved from side to side on one side, the other is faceted into two narrow side planes and a wide central plane. Given the early and secure context of this tool, I jocularly nicknamed it WOST ("World's Oldest Socketed [Metal] Tool"), an acronym which has unfortunately gained more publicity—including taking the nickname seriously—and longevity than I ever intended! Initial qualitative analysis carried out by the Thai Department of Mineral Resources in 1968 suggested that the tool was made of hammered native copper; however, the presence of phosphorous argues for a smelted source for the copper. Subsequent analyses of the only other two metal fragments from this level using an electron microprobe also revealed that these two samples (and by implication "WOST" as well) were in fact tin bronze, with about 5% Sn (Bayard 1972). Quantitative analysis carried out by Maddin (pers. comm.) indicates that "WOST" is in fact 17% Sn, a percentage much higher than would seem desirable in a cutting or digging tool of this sort.

"Non Nok Tha produced a relatively large number of bivalve moulds and mould fragments, as well as unfinished sandstone blanks. In all cases these were made of locally occurring Phra Wihan and Phu Kradung sandstone; not surprisingly, clay moulds more characteristic of late First Millennium sites like Non Chai (Bayard *et al.* 1982-83) and the upper layers of Ban Na Di (Higham and Kijngam 1984:128) were not found at Non Nok Tha. Although the latest one or two levels of the Middle Period very likely overlapped the period of economic "takeoff" in the region, clay mould casting—like iron tools—seemed not to have reached the site prior to its abandonment".

Alloys: "Similarly, no really clear-cut pattern appears in bronze alloy variation through the span of the Middle Period. Higham and his associates have documented a transition at Ban Na Di from a more or less uniform use of low-tin (2-12%) bronze to the use of a range of alloys, including leaded tin and very high tin. The transition coincided with the abandonment of the cemetery at the site and the beginning of manufacture of specialty items like bronze bells (Higham and Kijngam 1984:106-7; Higham 1986:7-11). The more or less uniform use of low-tin alloys was thus the norm from about 1500 BC until layer 5, at about 100 BC. Given the relative chronologies of the two sites we would also expect a uniform use of low-tin bronze throughout the Non Nok Tha Middle Period, the end of which coincided with the abandonment of the site and the economic and technological "takeoff" evidenced at Non Chai (Bayard *et al.* 1982-83), the Ban Chiang Late Period (White 1982), and layer 5 at Ban Na Di.

"However, the Non Nok Tha Middle Period bronzes exhibit a considerably wider range of alloy variation than those of Ban Na Di layers 8-6. Figure VI-4306 presents a graphing (by MP 1-4, MP 5-8, and LP levels) of tin vs lead percentages for 44 artefacts analyzed by Rajpitak (1983); and 48 lumps and nodules analyzed by Rajpitak (20 analyses) and Selimkhanov (28 analyses of 11 pieces). As the latter were done using spectroanalysis only (Selimkhanov 1979:33),

they should perhaps be viewed more cautiously than Rajpitak's. The analyses done by Rajpitak shown here do not include badly corroded specimens with less than 70% copper present in the analysis.

"When compared to a similar figure for 39 Ban Na Di artefacts (Higham 1986: fig. 12) it seems clear that while overall tin content is roughly the same for the Non Nok Tha Middle Period artefacts and layers 8-6 at Ban Na Di (0-15% as compared to 2-12%), there is more variability in lead content during the latter Middle Period than exists in Ban Na Di layers 8-6; Late Period Non Nok Tha (late First Millennium AD on) specimens predictably exhibit the same wide range of lead content as the earlier layer 5-3 specimens from Ban Na Di. The use of leaded bronze alloys obviously has considerable antiquity at Non Nok Tha, not surprising given the occurrence of lead bronze alloys in late Phung Nguyen contexts (Murowchick 1986:2); rather more surprising is the uniformly low lead content in the 13 early Ban Na Di artefacts analyzed.

"Factor analyses of the Non Nok Tha bronzes present a pattern similar to that found at Ban Na Di (Higham and Kijngam 1984:116-20). Rather than list lengthy tables of factor loadings for each artefact analyzed, we instead utilize a Q-mode analysis based on elements rather than objects, using the six elements detected in the vast majority of artefacts; we also limit the sample to the 87 artefacts analyzed by Rajpitak, excluding the spectrographic results obtained by Selimkhanov (which give no percentage figures for Cu). The sorted results from the SPSSx program are shown in Table VI-C).

Table VI-C Varimax Rotated Factor Loadings on 87 Non Nok Tha Bronze Specimens (as in Bayard in press)

	FACTOR 1 (37.6%)	FACTOR 2 (22.9%)	FACTOR 3 (17.2%)
As	.834	—	—
Sb	.820	—	—
Pb	.687	—	-.313
Cu	—	.897	—
Fe	—	-.880	—
Sn	—	—	.939

"Instead of the sharp contrast in variability of tin and lead evidenced by the Ban Na Di bronzes, the first factor in the Non Nok Tha analysis subsumes variation in arsenic, antimony, and lead (the first two as minor trace elements, of course); the second contains copper; and the third subsumes the variability in tin. The degree of variability of both tin and lead throughout the assemblage (as opposed to little or no lead admixture in the earlier Ban Na Di bronzes) may account for the placing of lead and tin in different factors.

"Analysis of lumps and nodules at Non Nok Tha—most of them presumed to be casting spillage—produces a quite different pattern. Tin content is considerably more variable, but this is true only when the spectrographic analyses are taken into account; however, lead content is uniformly low: from 0/trace only to 1% in MP 1-4, 0/trace to 4% in the later Middle Period, and 0/trace to 2.5% in the Late Period. Either lead was being added separately to the molten bronze, as suggested above, or a considerable amount of lead has leached out of these usually very small and corroded specimens. However, some ring and bracelet fragments are also very

small and corroded and yet contain a considerable proportion of lead. On the other hand, it is difficult to envisage bronze casters being more spill-prone before adding lead to their crucibles than afterward! Only further analysis of a much larger body of samples from a larger number of sites will provide a definitive answer.

"A final point about the bronze nodules and droplets: when the number and weight of nodules for each of the two excavations is plotted against the intercalated overall sequence of levels, a satisfying degree of congruence is present. Peaks in both number and weight of nodules occur at the same points in both sequences: MP 1, MP 5, and LP 2, with additional peaks at 1966 MP 3, MP 8, and LP 1, not present in the 1968 area (Bayard 1981). These presumably reflect periods of more or less intensive bronze-casting at the site".

Typology

"As the bronze materials from Non Nok Tha were less variable than those from Ban Na Di (in particular, claw-shaped beads and the bronze bells characteristic of the upper Ban Na Di layers are absent), it is not possible to present a fine-grained typology of such artefacts as bronze bracelets. However, we can definitely speak of three types: plain circular section, plain D-section, and decorated circular. The majority of these are made of leaded bronze; only the 15 plain D-sectioned bracelets worn by 1966 MP 5 B. 31 have low (but perhaps still intentional) lead content.

"The five bronze axes and six major axe mould finds allow a general but obviously very tentative typology of bronze axes to be postulated:

A) Trapezoidal axes with sides slanting in toward blade (NNT-152; "WOST"); this "type", represented by only one specimen with a blade consisting of a mass of corrosion, is obviously ill-defined, but seems rare in other sites. The only general parallel which comes to mind is an undated specimen from the Mlu Prei area (O Pie Chan) pictured by Levy (1943:Pl. XXII, 3).

B) Trapezoidal axes with sides sloping outward to blade, and blade often flared and "horned" (mould NNT-530, axes NP-549, NNT-630). The three specimens range from MP 1 to MP 4 at the site, and are fairly common throughout the region.

C) Axes with semi-lunar or diamond-shaped blades (moulds NNT-529, NP-82, NNT-36, axe NNT-528). The four specimens span MP 1 to MP 6 at the site; the type occurs widely throughout Southeast Asia.

D) As above, but with smoothly rounded shoulders producing an ovoid axe; the only example is the mould pair NP-550, from MP 2, and in fact the type appears to be quite rare on the mainland of Southeast Asia (although it occurs in the Philippines; *e.g.*, Solheim 1967: fig. 3A). Higham illustrates a vaguely similar specimen from Samrong Sen (1986: fig. 161), presumably after Noulet (1879: Pl. VI,6); however, this axe has a slight shoulder on one side, and appears from the original plate to have been more pediform than oval in shape when cast, with its asymmetry largely removed by subsequent corrosion.

E) Axes with widely extended "wings" and either a straight or slightly curved blade (moulds NP-107, NP-310, axe NNT-527). These appear to be limited to MP 5 and MP 6 at the site, although it is of course impossible to be conclusive with such a small sample. The type is quite distinctive, and even general parallels are difficult to find elsewhere.

"Given the small sample of axes and moulds, little can be said save that types B and C, fairly widespread elsewhere, enjoyed a fairly long period of popularity at Non Nok Tha during the Middle Period, while type E is apparently limited to the later part of the period. The position

of type A ("WOST") remains problematical until more excavations of sites, which also bracket the transition to bronze technology are carried out. Like Ban Chiang, typical bronze objects from Non Nok Tha are socketed axes and bangles, and most of them come from burial contexts. The burials are roughly grouped into the categories of poor, wealthy and very wealthy, and bronze objects and artefacts associated with bronze manufacture are limited to the wealthy burials (Bayard 1980:192, 195, 199).

"These bronze objects were subjected to chemical examination, and discovered to be alloys of copper, tin, and lead. Bayard (1980: 194) believes that both tin and lead were deliberately added because the proportion of tin is generally in the optimal range (Selimkhanov 1979: 37) to maximise the strength of the alloy and to minimise brittleness, and because lead may have improved the casting qualities of the alloy.

"The socketed objects are, like in Ban Chiang, cast in bivalve moulds (Bayard 1980:197). Smith (1973: 28) observes the evidence of cold working and annealing to shape and strengthen the working edge. As for the bracelets, both Smith and Stech-Wheeler and Maddin (1976: 43) suggest the possibility of casting by the lost-wax method because there are no seams. Stech-Wheeler and Maddin (1976: 43) add that there is some indication of fast cooling, which would occur if the wax had been embedded in a thin clay rather than a stone mould. This evidence suggests a fairly advanced metal working operation utilizing all the available techniques.

"Like Ban Chiang, bivalve moulds made of locally occurring sandstone have been recovered at the site, indicating that casting took place at Non Nok Tha. However, the excavators have discovered no trace of slag from smelting (Bayard 1980: 1934; Labbe 1985: 27). The difference between Ban Chiang and Non Nok Tha is that the latter has yielded far more fragments of moulds than the former. White (1982: 44) speculates that this was due to functional differences between the two sites. Another possible explanation is that while Non Nok Tha is located near potential ore sources and sandstone sources, more casting relying on sandstone moulds took place. On the other hand, at Ban Chiang, bronze workers had to use clay moulds for lost wax".

BAN NA DI

At the site of Ban Na Di located only 24 kilometre southwest of Ban Chiang, eight layers have been recovered and dated as follows: Layer 8 c.1200-900 BC; Layer 7 c.900-500 BC; Layer 6 c.500-100 BC; Layer 5 c.00 BC-AD 200; Layer 4 post-dates AD 200. Layers 8 through 6 belong to General Period B (Higham 1988: 132). Layer 8 corresponds to Phase III of Ban Chiang, Layers 7 and 6 to Phase IV. The site is 5 ha in area, and the entire surface of the site is densely packed with copper smelting debris, suggesting the industrial scale of production. Nearly all the bronze objects at Ban Na Di come from burial contexts. The most abundant artefacts are bangles, and axes and arrow points have been found, but no socketed spearheads have yet been identified. The artefacts are made from 10% tin bronze (Higham 1984: 140;1988: 134-38).

In addition to the bronze artefacts, the site has yielded a wealth of data concerning bronze production, such as clay furnaces, numerous fragments of crucibles tempered with rice husks (Higham 1984:140; 1988: 133-34). Based on the discovery of a fragment of a lead cast, Higham (1984: 140) has reconstructed the unique lost-wax casting technique, which presumably took place at Ban Na Di: the metalworkers carved a two-piece master mould out of sandstone and filled it with lead, which has a much lower melting point than bronze and was less likely to crack the stone. The lead casts were then invested with clay. When the clay and the lead were heated together, the clay was baked hard and the lead ran out. The clay moulds were then filled

with bronze. The metalworker prepared the bronze by placing the wanted proportions of copper and tin in a clay crucible that was heated in a charcoal-filled furnace under a forced draft.

Regarding Thai metallurgy Sasaki (in press) says that although there is some regional variation from one site to another, in general, the majority of bronze artefacts prior to the introduction of iron are ornamental, such as bracelets, anklets, and neck ornaments. Also common are bronze bells, socketed adzes, axes, and other socketed tools. Socketed spearheads are not very common. Small arrow-heads and small fish-hooks are occasionally discovered. Nonetheless, the data are likely to be biased because almost all of them come from the burials. These bronze objects were made with a sophisticated technology in which the techniques of alloying, bivalve casting, lost-wax technique, cold working and annealing were all utilised (White 1988:177-79).

VIETNAM

Recent archaeological evidence shows that there was a long history of bronze metallurgy before the Dong Son culture. The periods under consideration are: the Late Neolithic Phung Nguyen (c.2000-1500 BC), Dong Dau or Lung Hoa (c.1500-1000 BC), and Go Mun (c.1000-500 BC). The dates are still debated, and these are rather conservative figures (Davidson 1979: 99; Murowchick 1988:183).

Vietnamese archaeologists hold that the Phung Nguyen culture belongs to the Bronze Age. Although no complete bronze implements dating to this period have been discovered thus far, a few sites, such as Go Bong, have yielded corroded bronze nodules and other remnants and scraps (Huyen 1984:173; Murowchick 1988:183). Davidson (1979: 99) cites Vietnamese archaeologists' speculations that the Phung Nguyen people had knowledge of bronze because the holes of opal sting-beads and of "tubes" of semi-precious stone for necklaces were probably drilled with bronze tools.

Sites of the next phase, the Dong Dau culture, have yielded bronze arrow-heads, fish-hooks, spearheads, and socketed axes in a variety of shapes (Murowchick 1988:183-84). At the site of Dong Dau itself, archaeologists discovered stone moulds for labour tools and weapons (Davidson 1979: 102). Bronze discovered at the Dong Dau culture sites are alloys of roughly 80 per cent copper and up to 20 per cent tin. Particularly the spearheads and arrow-heads were found to have such high proportions of tin (Huyen 1984: 175; Murowchick 1988:183-84).

Murowchick (1988) briefly reviews the current Vietnamese evidence tracing bronze metallurgy through the second and first millennia BC and present lab analyses of selected Late Bronze Age Vietnam and the recent analysis of selected Kampuchean bronzes in the Peabody Museum collection suggest that the often maligned Kampuchean bronze finds made decades ago warrant a vigorous revaluation.

The following description of the Vietnam metal technology is mainly based on Murowchick (1988: 182-99).

In the Red River delta of northern Vietnam, the Late Neolithic-Bronze Age sequence spans four basic periods: (1) late Phung Nguyen or Go Bong (Late Neolithic/Early Bronze Age, c.2000-1500 BC), (2) Dong Dau (Middle Bronze Age, c.1500-1000 BC), (3) Go Mun (Late Bronze Age, c.1000-500 BC), and (4) Dongson (Terminal Bronze Age/Early Iron Age, c.600-258 BC).

Late Phung Nguyen or Go Bong Period (c.2000-1500 BC): First discovered in 1959 at the site of Phung Nguyen in Vinh Phu Province, the so-called Phung Nguyen culture complex is now represented by more than 100 sites, of which some 300 sites of the Go Bong Period are concentrated along the Red and Black rivers, including Dau Duong, Phung Nguyen, Lung

Hoa, Dong Dau (lower levels) in Vinh Phu; Tu Son at Ha Bac; Van Dien (lower levels) at Hanoi; and Chua Gio and Hoang Ngo at Ha Tay. A radiocarbon date of 1650 BC has been obtained from the lower levels at Dong Dau, whereas Trang Kanh (Hai Phong province) has yielded a date of 3405 ± 100 BP (Klein midpoint: 1760 BC) (Tan 1980, p.126; Bayard 1984, p.309). It is interesting to note that this concentration of Phung Nguyen sites corresponds exactly to the traditional location of the first "kingdom" of Vietnamese legend, that of the Vanlang under the Hung kings. Other possible indications of metallurgy are the presence of tubular beads of opal and other semi-precious stones found at the sites of Phung Nguyen and Go Bong; various Vietnamese archaeologists (cited in Davidson 1979: 100) have suggested that only a tiny metal drill could have been used to produce the holes. A small lead-bronze awl and bronze wire fragments were found in 1974-76 among the remains of the Hoa Loc culture in the coastal region of Thanh Hoa just to the south of the Phung Nguyen centre. The dating compared to the site of Ma Dong (Hanoi province), which produced similar pottery and has been radiocarbon dated to 2738 BC (Huyen 1984: 175; Bayard 1984: 309), yet no metallic artefacts have been found at this site (Murowchick 1988).

Dong Dau Period (Middle Bronze Age, c.1500-1000 BC): Sites from the Dong Dau Period are distributed over approximately the same area as those of the late Phung Nguyen. Indeed, many sites contain Phung Nguyen remains in the lower levels with Dong Dau levels of Vuon Chuoi (Ha Son Binh Province) yielded a radiocarbon date of 3070 ± 100 BP (Klein midpoint: 1343 BC) (Tan 1980, p.127); (Bayard 1984, p.309), whereas the type site of Dong Dau produced a date of 1377 ± 100 BC (Long 1975, p.55). Dong Dau pottery types share many features with the Go Bong material, suggesting a direct development from the preceding period. Although stone artefacts (polished stone axes, rectangular adzes, bracelets, and earrings) are still dominant, bronze is now much more common than in late Phung Nguyen sites. Dong Dau sites have yielded bronze arrow-heads, fish-hooks, spearheads, and socketed axes in a variety of shapes. Of particular interest is the appearance of the asymmetric pediform axe that becomes quite common at later Dongson sites. Metallographic analyses of some of these bronze artefacts show that they are alloys of roughly 80% copper and 20% tin [Tan (1980, p.128), citing Phi *et al.* (1970)]; other analyses on seven Dong Dau bronze artefacts revealed a tin content ranging from 11.5% to 19.0%, with a spearhead and arrow-head having unusually high proportions of tin [Selimkhanov (1984, p.275), citing Tylecote (1981, p.35)]. Clay and sandstone bivalve moulds for the casting of axes, chisels, and arrow-heads have also been reported from sites of this period.

Go Mun Period (Late Bronze Age, c.1000-500 BC): Sites of the Go Mun Period are concentrated south of Vinh Phu along the Red and Black rivers and are also found further south in the Ma river delta in Thanh Hoa province. For the first time bronze implements actually outnumber those of stone. For example, at the site of Vinh Quang (Ha Son Binh province), radiocarbon dated to the 11th century BC, 62% of the tools are bronze (Tan 1980, p.128). These include a variety of tall socketed spearheads with a pronounced central rib, virtually identical with the common forms found in subsequent Dongson levels. The socketed axes and adzes also take a variety of shapes, some bearing simple thread relief decoration near the socket (Long 1975, figs. 117-30). Finely cast arrow-heads with barbs and tangs, fish-hooks, bracelets, small cast figurines of domesticated animals, and sickles with a medial rib and transverse socket have also been found.

Dongson Period (Terminal Bronze Age/Early Iron Age, c.600-258 BC): Many Dongson sites yielding a rich diversity of bronze goods have been excavated in northern Vietnam since

the 1920s. Although this bronze culture was long held to have developed only under Chinese influence, Vietnamese archaeologists now strongly believe that Dongson metallurgy was the culmination of an unbroken line of development in the Red and Ma river deltas of northern Vietnam from the Phung Nguyen through the Go Mun periods (Tan 1980). Numerous radiocarbon dates securely place the Dongson Period in the mid to late first millennium BC. The rich diversity of bronze goods from major sites such as Viet Khe and Lang Ca includes such tools as knives, chisels, ploughshares, and axes, vessels, and musical instruments, including the highly decorated bronze drums and bells. Weapons such as daggers, spearheads, and swords are much more common at Dongson sites than at Bronze Age sites in central or southern Vietnam. It is quite possible that this is related to increasing contact with the contemporaneous Dian culture of Yunnan (which shares many cultural traits with Dongson) and other northern groups which are well documented as having engaged in warfare for the capture of booty, slaves, and sacrificial victims. By the late first millennium BC, cast iron was widely used at Dongson sites (Huyen 1984, p.176); these include a large number of iron tools and weapons as well as a few bimetallic weapons.

Laboratory analyses are providing further information about Dongson metallurgy. Seven Dongson bronzes selected from the collection of the Peabody Museum of Archaeology at Harvard University were analysed by Hedy Yuen in 1984-85. All of these pieces were excavated at Thanh Hoa or purchased from villagers living near the site by Olov Janse. A wedge-shaped sample of bronze was removed from each artefact using a rotary Dremel Moto-tool; the wedge was mounted in epoxy, then ground, polished, and etched according to standard metallographic practice. Further samples from each artefact were analysed by J.F. Merkel following the guidelines suggested by Hughes *et al.* (1976) and Matterson *et al.* (1981). When etched with potassium dichromate, the spear samples clearly showed dendritic structures, indicating that they were cast; a subsequent etch of ferric nitrate + hydrochloric acid + water revealed annealing twins and heavy strain lines indicating that the blades were cold-worked, probably to increase their hardness. Dagger 7692, a beautiful specimen 20.3 cm tall with an upturned curl flanking the blade at each side of the top of its hollow handle, was cast in one piece, the blade being hammered and annealed to increase its hardness. Strain lines from cold-working are also seen in samples taken from one of the other two dagger blade fragments. The slightly later Han bowl from Man-thon, measuring 9.7 cm in diameter and 3.8 cm tall, was expected to show that its very thin walls (1.35-1.70 mm) were produced by hammering; quite to the contrary, the potassium dichromate etch revealed that the vessel was cast, the beautiful cored dendritic structure showing no evidence of post-casting treatment. A most interesting discovery of clay bivalve moulds from the third century BC Dongson necropolis at Lang Ca provides clear evidence of how small bronzes such as these might have been cast.

SA HUYNH CULTURE

The middle period of Southeast Asia Huynh is named after the site of Binh Chau, although some scholars feel that Binh Chau represents a separate culture, as many ceramic features distinguish it from purely Southeast Asia Huynh sites. Binh Chau has yielded a number of broken pottery crucibles with inward-turning rims as well as fragments of pottery casting moulds. Finely cast bronze implements include arrow-heads. No radiocarbon dates are yet available from this site, and heavy disturbance of the stratigraphy from construction and combat during the Vietnam war has cast doubt on some artefact associations. The excavators, however, date Binh Chau to the late high level of bronze casting technology at this site which is fully comparable to that

from Go Mun and Doc Chua. The final period of Sa Huynh is represented by a variety of sites in the Nghia Binh, Dong Nai, and Da Nang region. The use of bronze drastically declines whereas iron axes, sickles, hoes, spades, spears, knives, and swords become common. Most of the limited bronze finds are bracelets (Murowchick 1988).

VIETNAM METAL TRADITION IN A WIDER PERSPECTIVE

Geological survey of Vietnam and Kampuchea has shown that the distribution of ores needed for bronze metallurgy is uneven. Northern Vietnam is rich in copper, tin, and lead ores easily accessible to the ancient metalworkers of the area. It is possible that trade along the Red river made the abundant ore sources of Yunnan available to the northern Vietnamese bronze centres, but this trade was certainly not a necessity for the development of bronze in the north. The situation in the south, however, was quite different. Although tin sources are known to exist at the head of the Dong Nai river, southern Vietnam is notably lacking in copper and lead ores. The same situation is found in Kampuchea. Lead, tin, and zinc indications have been located west of Phnom Penh, but virtually no exploitable copper sources have been found near Samrong Sen or Mlu Prei.

This being the situation, the increasing evidence of local remelting and casting of bronze in southern Vietnam and Kampuchea suggests that a vibrant trade in crude metals (rather than the ores themselves) was taking place along the Mekong river from the north. A number of recent archaeological developments in Thailand have yielded supporting evidence of this ancient metals trade. Recent excavations at the ongoing research of the Thailand Archaeometallurgy Project jointly organised by the University Museum of the University of Pennsylvania and the Thai Department of Fine Arts, has yielded a prehistoric copper mining complex on the banks of the Mekong river (Pigott *et al.* 1985). The site, dated to the second half of the first millennium BC, has yielded evidence of the ancient mining of malachite and native copper. The excavators believe that the huge amount of mining debris may indicate that the site was being worked much earlier than the radiocarbon dates indicate. Further work at this site will certainly clarify the situation. It is certainly possible that similar ancient mining activity was taking place on the Laotian side of the Mekong, where tin, lead, and copper sources are also found, although the paucity of archaeological work here makes such a claim difficult to support at this time.

Further evidence of a prehistoric trade in metals comes in the form of actual ingots looted from two Ban Chiang culture sites located near the site of Ban Chiang itself. As is the case with most looted antiquities, details surrounding the find are sketchy. At least twenty-five circular ingots were found, ranging in size from 4 cm to 5 cm in diameter and 1-2 cm thick and weighing between 60 g and 130 g. They were apparently cast in roughly carved depressions. Although they have not yet been analysed, their green corrosion suggests that they are made of copper or bronze. Three of the ingots are black and may prove to be pure tin. The looters reported that the ingots from the two sites were found grouped together "as if they had been in bags". It is certainly possible that metal ingots such as these served as a form of currency in ancient Southeast Asia.

Excavations carried out by the Thai Fine Arts Department in the area of Lopburi, some 140 km north of Bangkok, has yielded a rich assortment of pottery moulds, casting debris, and slag. The moulds include a large number of small conical shapes in fairly standardised sizes; these might have been used for the casting of standardised ingots, perhaps for trade. The terrain between central Thailand and Kampuchea or southern Vietnam presents no great barriers to such a trade

over land. However, it is also believed that the southern coast of Thailand reached much farther inland than the present shoreline; during the second millennium BC the Lopburi area might have been only 10 or 20 km from the coast, suggesting that maritime trade with the rest of Southeast Asia was a possible route for the transmission of metals to resource-poor regions. It should be noted that the four-point earrings and animal-headed earrings typical of the Sa Huynh culture have been found at Dongson sites in the north. The date, nature, and extent of this metals trade with Kampuchea and Vietnam must await further archaeological and geological work in the region, but the similarities and increasing quantities of ancient metallurgical finds and the absence of exploitable ores in the south strongly suggest that such a trade must have flourished during the second millennium BC.

Recounting the unsolved problems Murowchick says that despite recent advances, major questions remain unanswered. Did the development of metallurgy in Southeast Asia necessarily involve a period of copper tool use (as seen in other parts of the ancient world), or was such a stage unnecessary in this region of abundant tin sources? What was the nature of influence between the Neolithic and Bronze Age cultures of Yunnan, which apparently enjoyed its own indigenous development of metallurgy while engaged in a variety of contacts with contemporaneous cultures of Sichuan and Gansu? Were the metallurgical developments in northern Vietnam influenced at all by the early metallurgy of Northeast Thailand? What was the nature of the relationships among the cultures of north, central, and southern Vietnam? And if coastal trade was involved, might it not also have involved the coastal regions of the Gulf of Thailand giving further access to areas with abundant tin and copper sources?

Vast areas of Southeast Asia remain archaeologically unexplored. Our understanding of the development of bronze metallurgy in Vietnam has greatly increased during the past few decades, but at present archaeological evidence provides little more than a preliminary chronology for this early bronze metallurgy in Kampuchea. It is weak if it must stand alone, but it is strengthened by virtue of its similarity and geographic proximity to well-excavated finds from the Dong Nai basin. Lab analyses are helping to reveal valuable details from those finds already made, but thorough surveys and re-excavations of those sites already known are needed to establish firm dates for these finds (Murowchick 1988).

SUMMARY

We thus see that there is a good case for an independent origin of the Southeast Asian metallurgy. It has a distinct utilitarian and non-elitist character reminding one of the Harappan metallurgy. The volume of copper production however suggests exports also. The evidence – both linguistic and circumstantial (archaeological) – suggests a link, though tenuous at this stage, with the Indian Copper Hoards Culture through the Himalayan corridors and movements of the Mon Khmer speaking peoples.

Southeast Asia is culturally connected with East Asia which we will take up in the next chapter.

CHAPTER 10

EARLY METALLURGY IN CHINA AND JAPAN

CONTENTS

- EARLY METALLURGY IN CHINA
- BEGINNINGS OF BRONZE AND IRON METALLURGY IN JAPAN
- SUMMARY

EARLY METALLURGY IN CHINA

(For this section on Chinese archaeometallurgy, I have mainly depended upon Ken Sasaki's work [in press] and am grateful to him for allowing its liberal use. Other important sources used are Chang [1983], Hua Zeming [1997], Zhu Shoukang [1982], Barnard [1983], Franklin [1983]).

We begin our discussions of East Asian archaeometallurgy with China as the Japanese archaeometallurgy has basically derived from the Chinese and the Korean sources and is much later than the former.

The Chinese technological evolution has great relevance to the understanding of urbanisation processes, especially in the Ganga valley. Recent researches by Yasuda's team in the Yangtze valley in China have shown that even in a forest environment agriculture and ceramic technology could arise very early though urbanisation followed almost ten thousand years later. In the Ganga valley too though early agriculture goes back to early Holocene, the urbanisation had to wait till the mid-I millennium BC.

Yasuda reports, "With the development of Chinese archaeology, new evidence of the origins of pottery has recently been revealed. ^{14}C dating (uncalibrated) shows that the oldest Chinese pottery dates back to the late last glacial maximum. The pottery which was unravelled at the Miaoyan site and the Tongliuzhou Dalong site in Guangxi Zhuangzu Ziziqu dates back to 16,000 years BP (uncalibrated). Moreover, pottery dating back to 14,000-15,000 years BP (uncalibrated) was found at the Xianrendong and the Diaotonghuan sites in Wannianxian Jiangxi province, and the Yuchanyan site in Hunan province. The oldest pottery which I saw at the Cultural Relics and Archaeological Institute of Hunan province was unearthed from the Yuchanyan site in Hunan province. The pottery is greyish, pointed based and around 1 cm in thickness. Pottery, which is as old as in the southern China, is also found at Shimomouchi site in Nagano prefecture in Japan. It is ^{14}C dated to 16,000 years BP... All the sites are in a forest.

"The people, who settled down at one place and invented pottery, started rice cultivation. Rice cultivation originated in the middle of the Yangtze Basin. ^{14}C dating revealed that the Xianrendong and the Diaotonghuan dated to 14,000-12,000 years BP and Pashidang and the

Pentoushan sites to 11,000-9,000 years BP. These are more than 5,000 years older than the Hemdu site in Zhejiang province. Earlier the Hemdu site was considered to be the oldest rice cultivation site and dated to 7,000 years BP. The oldest pottery was also found at these oldest rice cultivation sites.

"Sedentary life began in a forest and people who invented pottery started rice cultivation. Forests were expanding from the late glacial period to the post-glacial period when climatic change was catastrophic. People adapted to the environment of forests and wet steppes, and started settling down in a forest. That became a trigger to master the techniques of plant cultivation.... In the backdrop of developing rice cultivation, urban civilization emerged on the Yangtze river basin 5,000 years ago. Walled towns appeared around that time" (Yasuda 1999).

With this backdrop, we turn to Chinese archaeometallurgy. (For Chinese chronology see Table 10.3.)

On the origins and character of the Chinese metallurgy, a number of scholars have expressed different views with differing perspectives. We will discuss some of the views below. In contrast to India, it has to be noted that Chinese metallurgy is both monumental (see for example, Figs. 10.1 to 10.4) and elitist.

About the Chinese metallurgy Hua Zeming (1997) says, "By the latter part of the third millennium BC, metallurgy had come into being in a number of regions, and many kinds of metal materials like red copper, primitive brass, tin bronze, and lead-tin bronze were already used for small implements and ornaments. The Xia Dynasty (21st century BC-16th century BC) had evolved into the Bronze Age. In Erlitou Cultural Ruins, Yanshi county, Henan province, remains of foundry workshops have been discovered where bronze sacrificial vessels, weapons, implements, and casting moulds have been excavated. Apparently, the making of articles was done with casting as the main means.

"The earliest copper-mining and smelting ruins known in China are located in Tongling (meaning copper ridge), Ruichang county, Jiangxi province. Its mining can be traced back to the 14th century BC. The shafts and drifts were supported by timber frames. Also excavated were ore-dressing troughs and wood winches for hoisting. Further study reveals that during Shang-Zhou Periods (Shang Dynasty: 16th century BC-11th century BC; Western Zhou: 11th century -771 BC; Eastern Zhou: 771-221 BC) the mining of copper minerals had progressed to a rather large scale in the Liao river valley and Yellow river valley, especially in the middle and lower reaches of the Yangtze river. The smelting of copper was done in semi-continuous operation in shaft furnaces. By the late Western Zhou at the latest, copper sulfide minerals had been used to smelt copper. The smelting technologies of lead and tin were mastered from the Shang Dynasty onwards. The lead vessels unearthed in Anyang have a purity of over 95%. Tin ore deposits were scattered in the Northeast, Northwest, and South China regions, especially in Jiangxi, Guangxi, and Yunnan, where tin reserves were very abundant. The early tin material must have come from these regions.

"Alloying techniques improved greatly during the Shang Dynasty. The sacrificial vessels of imperial courts unearthed in Yin ruins have a tin content of 18% or more. The book *Kao Gong ji* of the Warring States (475-221 BC) recorded something about the alloy proportioning of *liu qi* (six kinds of bronzes): *zhong* (bell), *ding* (cauldron), *fu* (hatchet), *ji* (halberd), *jian* (sword), *zu* (arrow-head), and *jing* (mirror). This indicates the craftsmen's clear understanding at that time that the mechanical performance of tin bronze varies with different contents of tin.

"Shang-Zhou bronze culture was characterised by sacrificial vessels, complex in shape and

delicate in design, which were mass-produced by casting. The key in achieving this characteristic without applying techniques such as the lost wax process lay in the skilful use of composite pottery moulds and various cast-joint technologies. Beginning with the Spring and Autumn periods (771-475 BC), it came in vogue to apply synthetically various shaping processes and decorating techniques: cast-joint, soldering, lost-wax process, forging, gilding, gold-plating, red-copper inlay, gold and silver inlay, engraving, etc. This significant change brought the manufacture of bronzes (Fig. 10.5) to a still higher level; the implements produced looked brighter and more colourful. As early as the late Neolithic Age, small sized gold objects had already appeared. By the Warring States periods, there were more and more articles made from gold, and coins were first minted of silver. These may have been obtained by cupellation, a refining process in which metals are oxidised at high temperatures, and base metals are separated by absorption into the walls of a cupal, or porous cup made of bone ash. The production of mercury also reached a certain scale. It is recorded that a great amount of mercury used to preserve bodies from decay was found in the imperial grave of Emperor Qin.

"In China, many of the most important inventions in ancient metallurgy were made before the sixth century BC. After the fruits in the preceding times were digested and imbibed in the Tang Dynasty (AD 618-907) and Song Dynasty (AD 96-1279), metallurgical technologies in China took shape, leading to further prosperity and greater achievements. For example, in the southern regions there was full scale mining and smelting of iron minerals and others such as copper, tin, lead, gold, silver, and mercury. There were also large and extra-large castings and bronze or iron structures, etc. It must be mentioned that the making of white copper (copper nickel alloy) was already mastered as early as the fifth century, and that during the Han and Tang Dynasties and later, metallurgy in China had exchanges with and mutual impact on the surrounding regions. Some examples are the westward spreading of iron-casting skills and the influences of Persian artistry on gold or silver wares in the Tang Dynasty. In the Song Dynasty, wet metallurgy was put into large scale practice to extract pure copper, annually yielding about five hundred tons, which amounted to about one third of the total copper produced in the whole country. About 1620 in the Ming Dynasty, it was possible to smelt zinc, which was used in great amount for minting coins. Antimony was smelted in the Ming Dynasty (AD 1368-1644), but it was not recognised at the time as a new kind of metal and thus was mistaken for tin" (Hua Zeming 1997).

Donald Wagner (1993) in last chapter of his book, *Iron & Steel in Ancient China*, also makes some very interesting observations regarding the origins of bronze technology in China. "In China bronze technology developed first in the north, where it was used primarily for weapons and for symbolic objects. The military and ideological power of Shang and Zhou depended in a large part on these two uses of bronze: production was heavily controlled and confined to some very large centres, such as the copper mining and smelting site at Tonglushan and the large foundries which have been found in close association with Shang and Zhou palaces. The dagger-axe - the primary weapon of the Chinese Bronze Age - is clearly designed for mass production; unlike the sword, which would seem to require more individual attention from the founder. This bronze technology, developed in an extremely hierarchical civilisation, spread in time to the more barbarian, less centralised, cultures in south and south-east China. Here, in production units, which were smaller and more closely associated with the final users of their products, the technology was developed in new ways. Besides technical and artistic innovations there was also a new development in the application of bronze: the production and use of bronze agricultural

implements" (Wagner 1993:405-6).

Chang, in his concluding chapter in *The Origins of Chinese Civilisation* (in Keightley 1983), also notices the fact that among all the components of early Chinese civilisation, the origins of bronze metallurgy and of writing have commanded particular interest. Unquestionably, he admits that both played crucial roles in the formation of early Chinese civilisation and they warrant the attention they have received.

Tracing the antiquity of metallurgy in China, Chang (1983) goes even further, "In a recent, posthumously published paper, T'ang (1979) stated that pieces of metal had long been known from Pan-p'o and Chiang-chai, in Yang-shao culture layers dated to the early fifth millennium BC. The circumstances of both finds had been described to me earlier by archaeologists at the Institute of Archaeology in Peking, and, it appears that the Yang-shao context of the Chiang-hai find, at least, is unassailable. The find was a small disc of brass, about 70 per cent copper and 30 per cent zinc. The metallurgical problems posed by such an alloy at this early date are difficult but not insurmountable. Small amounts of metal, furthermore, have been known from Ma-chia-yao, Ch'ü-chia, and Lungshan sites. Thus, whatever the Yang-shao situation, one does not feel too out of place in stating that some knowledge of metal working had always been part of the Chinese technological repertoire since sometime in the Neolithic. But there was no full-blown bronze metallurgy until the Bronze Age of Shang and Chou".

As mentioned above, Chang quotes Tang Lan's (1979: 4-5) discoveries of several metal objects from the Neolithic context in his posthumously published paper. Such discoveries include a fragment of copper at Banpo near Xi'an, Shaanxi province, a fragment of alloy at Jiangzhai, Lintong, Shaanxi province, a bronze knife dated to more than 5,000 BC at Majiayao, Gansu province, many copper tools at Huangniangniangtai, Vuwei, Gansu province, and a copper or bronze drill at Sanlihe, Shandong province. He suggested that Jiangzhai alloy might be of a modern product, and also stated that the details of Majiayao and Huangniangniangtai discoveries were unclear to him. Iijima (1985: 312) however questions the antiquity of these discoveries. He argues that if the stratigraphy is secure, these copper fragments should be of natural products, such as the case in which ore containing copper became copper as a metal by receiving accidental yet excessive heat from fireplace or furnace. If these copper items are real objects, like tools or accessories, they are likely to be modern products mixed into earlier strata.

Sasaki thinks that An's (1981: 270-2) critique is more specific than that of Iijima. An refutes the validity of the Banpo discovery that the copper fragment was discovered in the dirt above the M 156 rather than in the tomb of the Yangshao context, and that the fragment contains approximately 20 per cent nickel, which suggest a more recent date for the product. He also points out that the Jiangzhai metal contains 25 per cent zinc (*i.e.*, brass), and doubts that such metallurgical conditions to produce brass existed more than six thousand years ago. Although the members of the Archaeometallurgy Group, Beijing College of Iron and Steel Technology (1981: 290, 294) suggest, based on their metallurgical experiments that, it was possible to produce brass even before the term "brass" appeared in textual evidence in the AD 11th century. Sasaki tends to support An's scepticism and believes that the metal fragment was a product of a later age, at least Shang or Zhou when production of metal objects (Figs. 10.1-4) became extraordinarily advanced. An (1981: 272) also questions about the dates of Majiayao that bronze (not copper) product should not have appeared as early as 2575 to 2500 BC (3100-3010 BC calibrated). An (*ibid.* 273-74) also criticises the Sanlihe discovery arguing that excavators found the drill when they organised the excavated materials and the drill itself turned out to be of brass, containing

20 per cent zinc, indicating a later age for the artefact. He nevertheless suggests the possibility that bronze or copper objects existed in the Shandong Longshan culture because of the similarity in *leiwen* [thunder pattern] design and animal masks between the black pottery of the Shandong Longshan culture and bronze. Iijima (1985: 313) also considers such discoveries in Shandong and Shanxi provinces significant because this evidence may be related to the Erlitou bronze culture. (For discussion on Chinese brass see also chapter 12.)

Convincing evidence of the occurrence of metals for the period just before 2000 BC (Chang 1980a: 36) comes from sites of both the Qijia culture in Gansu and Qinghai provinces and the Lower Xiajiadian culture in western Liaoning province.

An (1981: 179-80, 182) gives a calibrated radiocarbon date, 2250 to 1910 BC, to the Qijia culture, but he also suggests that the later phase of the Qijia culture was contemporaneous with the Late Shang Period because of the similarity between a bronze mirror discovered in tomb M 25 at Gaimatai, Guinan, Qinghai province and those discovered in Fu Hao's tomb in Yinxu. The excavators of the Huangniangniangtai site in Wuwei, Gansu province believe that the Qijia culture lasted from the later Gansu Yangshao Period to the end of the Shang or the beginning of the Zhou Period because they speculate that the influence of Shang did not reach the present Gansu area in the Shang Period. This Neolithic tradition lasted even after the Zhongyuan (Central Plains of China) entered the stage of Bronze Age. Iijima (1985: 313) tends to believe that the Qijia culture was either contemporaneous with, or later than, the Erlitou and Erligang Periods.

The site of Huangniangniangtai has yielded a total of twenty-three copper objects. There are four copper knives, two of which are complete, representing three types. While one type shows the evidence of casting, the other two are made by hammering. Other discoveries include twelve drills, an adze, a ring, and a decorative object. At the Gaimatai site, the excavators have discovered the bronze mirror in tomb M 25, a circular copper decorative object, and a ring. The Qinweijia cemetery site in Yongjing county, Gansu province has yielded two rings, a circular decorative object, an axe, etc.

Metallurgically, the Qijia culture is characterised by the co-existence of red copper, tin bronze, and lead bronze. The culture also exhibits a variety of techniques: a knife from Huangniangniangtai and an axe from Qinweijia were made by the single-mould technique; a decorative object from Huangniangniangtai by a simple bivalve technique; and a mirror from Gaimatai by a more advanced bivalve technique (An 1981: 279). An (*ibid.* 279) argues that the Qijia culture entered the Bronze Age in its later phase. However, Chang (1980a: 37) notices that no traces of an aristocratic locus associated with bronze ritual vessels and weapons characterising the Erlitou and later Chinese Bronze Age have been discovered at the Qijia sites (Sasaki in press).

Below we discuss the Erlitou and Erligang Cultures in relation to the origins of Chinese metallurgy.

Dates of Erlitou and Erligang Cultures

Sasaki makes the following observations about the stratigraphy and dates of the Erligang, and especially the Erlitou cultures. At the site of Zhengzhou, the excavators have discovered three consecutive strata of Shang remains, namely (from the earliest) Lower Erligang, Upper Erligang, and Renmin Gongyuan (People's Park). Since the artefacts from the Renmin Gongyuan phase are found to be close to those from the Xiaotun, Anyang (Iijima 1985: 6), the two Erligang phases may be earlier than Yinxu. Two radiocarbon dates of the Erligang phases have been published: 3215±90 BP (calibrated to 1560±160 BC) and 3235±90 BP (calibrated to 1590±160

BC) (Xia 1977: 229). The results support the view that the Erligang phases are on the whole earlier than the dynastic period at Xiaotun, Anyang (Chang 1980b: 272).

A cultural phase even earlier than the Erligang phase is the Erlitou phase. Sites of the Erlitou phase are distributed in southern Shanxi province and north-western Henan province (Iijima 1985: 15), which coincide with the traditional geographic distribution of the Xia people. Remains of the Erlitou culture fall between those of the Henan Longshan and of the Erligang culture. The Erlitou culture is divided into four phases based on the stratigraphy and typology of the ceramics from I through IV. On the south wall of the trench Y.L.II T 102 at the Erlitou site, Henan, stratum 5 corresponds to Erlitou I, stratum 4 to Erlitou II, stratum 3 to Erlitou III. Important points are 1) that stratum 3 is earlier than the Upper Erligang phase, and 2) that stratum 5 belongs to the terminal Henan Longshan. However, we have not firmly grasped the chronological relationship between the Lower Erligang phase and Erlitou IV and between the Lower Erligang phase and Erlitou III (Iijima 1985: 39).

Sasaki reports two different views concerning the Erlitou sequence. One is the position that the entire Erlitou sequence from I through IV belongs to one cultural complex, namely the Xia Dynasty. Chang (1980b: 344-45; 1986: 316) is one of several scholars who represent this position. He points out 1) that all the radiocarbon dates for the Erlitou site fit within the dates for the Xia Dynasty known through legend, and 2) that, as Tong (1975: 29) has discovered, the geographical distribution of the Erlitou culture coincides with that of the activity of the Xia people. He also discredits the view that Erlitou was the early Shang capital of Bo by attributing the Yanshi Shang city (a site near Erlitou) to Bo.

The other view is that while Erlitou I and II represent the Xia Dynasty, the III and IV represent the early Shang period. Iijima (1985: 25) notices a significant difference in archaeological remains between the Erlitou II and III. For example, the appearance of a palace; beginning of the use of bronze objects, such as the *jue*, *ge*, arrow-head, and bell (whose forms are perpetuated in the Middle and Late Shang indicating that there was little break in development); increase in jade; and typological change in ceramics - all took place in the Phase III. Similarly, Yin (1986: 10-11) believes in such significant differences in archaeological assemblages. He parallels this change to changes occurring in society at that time, such as a dynastic succession.

When we discuss bronze objects dated to the Erlitou Phases III and IV, there are always two interpretations for them; either they represent the Xia culture or the early Shang Dynasty.

Evidence of metallurgy at Erlitou

The Erlitou site has so far yielded considerably more bronze objects than other sites of roughly the same time period (Iijima 1985: 21). Although Iijima states that bronze objects appeared for the first time in Phase III, An (1981: 281) refutes this, stating that remains of Phases I and II at Erlitou have yielded a small amount of smelting residue and fragments of a crucible, and argues that these represent the early phases of the Bronze Age.

The bronze objects represented in the Erlitou assemblage are the *jue*, *ge*, adze, drill, chisel, arrow-head, awl, knife, fish-hook, etc. (An 1981: 281; Iijima 1985: 296). These bronze tools were not necessarily cast by the sophisticated piece mould technique. An observes that most of the tools are cast in a simple mould because the back of the tool is flat. That an axe and drill cast in bivalve moulds does not have sockets indicates their primitive characters. On the other hand, *jue* which have been discovered at the Erlitou site and represent the earliest type of bronze vessels in the Chinese Bronze Age already show evidence of the piece-mould technique. Bagley

(1987: 18) speculates that "For a workshop experienced in the use of bivalve moulds, a mould of four or five parts offered a natural way to cast the small undecorated *jue*. The earliest type of *jue* is dated to Phase III. Two important facts concerning the history of Chinese metallurgy are: 1) that it is made of an alloy of 92 per cent copper and 7 per cent tin and 2) that, because of poor finishing, seams still remain on the surface. The seams indicate that it was cast in at least a four-piece mould.

Sasaki (in press)* discusses the positions of the main contending viewpoints concerning the beginning of metallurgy in China. "One is represented by Robert Bagley's position that there was wrought-metal-working in China before casting was known to the Chinese, and that the wrought-metal-working technique was probably introduced by foreigners. The other is Noel Barnard's idea that metallurgy in China is indigenous because the piece-mould technique and other aspects of early Chinese technology were quite unique to China".

But before we go into the evaluation of the two contending viewpoints by Sasaki, let us have a look at what Wagner has to say on this issue.

Wagner says, "There is a fundamental problem in the study of questions of diffusion of material culture which seems to have been entirely ignored in this debate. Consider two human groups, A and B, living at some distance from each other. Suppose that they share some element *x* of material culture (a pot shape, a bronze-casting technique, a fallowing system). This *x* may have been independently invented, or it may have been transmitted in one way or another from A to B or from B to A. If *x* was in fact transmitted, there may be some way of proving the fact. The terminology associated with *x* in the two places may be linguistically related. Some details of *x* may be shown to be practically unnecessary and therefore unlikely to be shared in independently invented versions of *x*. The traffic between A and B may be shown to have been so intense that the assumption of independent invention of *x* is unreasonable - as soon as *x* was invented, *e.g.* as it would have become known at B, so that independent invention at B was not a possibility.... Many other types of positive proof can be imagined.... But as C.S. Smith asks rhetorically, "Does transmission have to leave a record?" The answer, of course, is no. The hypothesis of transmission may be true but empirically unprovable. On the other hand, however, what traces will independent invention ever leave? It is difficult to imagine what sort of incontrovertible positive evidence could ever be found for independent invention. There is therefore a fundamental asymmetry in the debate Barnard and Sato (1975) show that bronze technology spread centrifugally from a single centre in north China. Then bronze metallurgy was transmitted to this centre without leaving a trace, or leaving traces, which have not yet been found. The ancient Chinese bronze techniques are very different from the ancient Western techniques, and do not include certain techniques (such as annealing) which were fundamental in the West. Then only the germ of an idea was transmitted, or else the Chinese recipients of the full Western technology accepted or developed only parts of it. And so forth.... It is necessary to acknowledge the fundamental asymmetry of debates concerning diffusion. The anti-diffusionists cannot hope to provide the sort of positive proof that the diffusionists may, under fortunate circumstances, be able to provide. It is therefore incumbent on the diffusionists to provide positive empirical evidence.... Broad untestable opinions such as those of Smith and Vasiliev quoted above are not useful in a scientific discussion" (Wagner 1993: 32-33).

* All references quoted in the excerpts from Sasaki (in press) can be found in his work. Only selected references are given in our bibliography.

Table 10.1 Chronological Table of Early Chinese Dynasties
(after Zhu Shoukang 1982)

Xia		21st—16th century BC
Shang		16th—11th century BC
Zhou	Western Zhou	11th century—771 BC
	Spring and Autumn Period	770—476 BC
	Warring States	475—221 BC
Qin		221—207 BC
Han	Western Han	206 BC—AD24
	Eastern Han	AD 25—220

We now present below a summary of the two positions discussed by Sasaki (in press).

Bagley's hypothesis

Bagley's wrought metalworking hypothesis is possibly based on the existence of the skeuomorphic features of pottery of the Qijia, Longshan, and Erlitou cultures. Such features include the two protuberances on the handles, presumably imitating rivets. Bagley (1977a: 198) believes that metal vessels existed perhaps as early as the beginning of the Second Millennium BC, and methods of fabrication other than casting seem to have been used by the Shang bronze founders. Chase agrees with Bagley by pointing out that some of the early bronze vessels from Panlongcheng and from Erlitou seem to be reproducing sheet prototypes in cast bronze.

Bagley (1977a: 197-98) does not think that metalworking technology developed in China. He explains: The entire inventory of Ch'i-chia (Qijia) pottery in its general character suggests the imitation of wrought metal shapes. Yet the finds of a few copper artefacts at Ch'i-chia sites offer faint encouragement for the assumption that these metal shapes originated in Gansu. Hundreds of Ch'i-chia sites are known, and at only three is there evidence of even the most primitive use of metal; while Ch'i-chia pottery shows a dependence on metal prototypes from the beginning. There is no sign of metallurgy in Gansu capable of aspiring to metal vessels, either in Ch'i-chia or even in its late successor cultures.

Consequently, Bagley suggests the possibility of a foreign origin of the metalwork in Gansu, especially in view of the fact that southern Gansu is at the start of later trade routes across Central Asia.

Arguing against Bagley's hypothesis, Barnard (1980-81: 7-18) says that: 1) the tubular spout can be achieved without inspiration from a metal prototype because the evolution of this aspect of pottery can be traced within the context of ceramics; 2) the projecting ledge between dome and body and the handle cannot be traced to its beginning (sheet metal) because the pottery *like* antedating examples from Erlitou H lack this feature; 3) when "imitation rivets" appear on handles, they are limited to the upper area of the handle terminals and there is nothing to hold the lower handle terminals to the vessel body; 4) "imitation folded rims" are simply a representation of the join-line or parting line which earlier formed between mould/core units, and in some cases it is an actual join-line; and 5) once such a fundamental knowledge as "annealing" is discovered or adopted by a metal-using culture, it would be impossible for the technique to have disappeared without a trace as Bagley argues for "discarding of a smithied technique".

Barnard's criticisms are very convincing, yet Sasaki thinks that these do not necessarily exclude

the possibility of wrought-metal-working completely; it only shows that skeuomorphic features of pottery can develop without the influence of metallurgy.

Barnard's hypothesis for the origin of metallurgy

Barnard assumes that the principle of annealing was unknown and that there was no metal-working in ancient China because so far no copper artefacts representing wrought-metal-working have been discovered. What had preceded bronze objects in China was instead pottery technology. Taking the similarity between pottery kilns and bronze casting furnaces and bronze workers' necessity to prepare for crucibles into consideration, Barnard argues that metallurgy in China arose in the context of advanced pottery technology. Barnard thinks that a potter would have needed merely to observe a trickle of molten metal issuing from a smelt, filling a natural depression in the ground, and solidifying. Immediately the idea of open mould casting of an artefact would arise and almost certainly be put into practice...(Barnard 1983: 270, 272).

The strength of Barnard's argument is his assumption of the metallurgists' close tie with potters, which is very likely because "the forms of some of... [bronze ritual] vessels continued or further developed ceramic types of the Neolithic and pre-Shang period". For example, Iijima states that early bronze *jue* are copies of pottery *jue*. Sasaki however thinks that Barnard's hypothesis does not completely exclude the possibility of foreign influence on the origin of Chinese metallurgy. He defends his position by pointing out the difference in crucibles between China and Europe in the Second Millennium BC and the uniqueness of the Chinese hinge (Barnard 1983: 254-69), but these cannot disprove the foreign influence. Sasaki does not believe in the possibility of migration of a large number of people with metallurgical skills either. But the foreign influence can be "as insignificant as the chance arrival of a single traveller in an area possessing both recognisable deposits of ores and the stone and ceramic technologies which would allow exploitation of the ores".

Sasaki's views about the origins of metallurgy

Sasaki thinks that if the Qijia culture was contemporaneous with the Late Longshan (Table 10.1) and Erlitou, there were two (maybe more) originally independent concurrent traditions of metallurgy in north China. The Qijia culture developed the use of copper tools prepared by cold-hammering technique.

The Qijia people could have learnt metallurgy from foreign travellers, but we do not know. At the same time, around the end of the Third Millennium or the beginning of the Second Millennium, BC, the Xia people at Erlitou gradually developed the casting technique based on their highly advanced pottery technology. This probably took place in the Erlitou I and II periods. At this stage, the bronze casting was not on an industrial scale, which characterised the Middle Shang Period and later, so it did not have a major impact on the society and its economy nor did it require complex social organisation. Probably they did not learn wrought-metal-working because none of the Erlitou culture sites have produced such discoveries. The Shang people then acquired the Erlitou metallurgy. The Shang Dynasty was very influential. It interacted with the Qijia people in the present Gansu and Qinghai provinces.

Following An and Iijima, Sasaki also thinks that it is more plausible, than the hypotheses of Bagley and Barnard. While it is very likely that metallurgy developed in the central plains of China in a unique way, the beginning of metallurgy in the Qijia culture seems independent from that of the Erlitou culture.

Table 10.2. Analytical Results of Some Qijia Artefacts
(after Zhu Shoukang 1982)

No.	Artefact	Site	Composition, %		
			Cu	Sn	Pb
1	plate	Dahezhuang, Yongjin, Gansu	96.96	0.02	tr.
2	ring	Qinweijia, Jongjia, Gansu	95	—	5
3	knife	Huangniangniangtai, Wuwei, Gansu	99.87	0.1 -0.3	<0.03
4	awl	Huangniangniangtai, Wuwei, Gansu	99.87	0.1	<0.03
5	mirror	Gamatai, Guinan, Qinghai	90	10	—

Table 10.3. Qualitative Analyses of Some Early Copper Artefacts
(after Zhu Shoukang 1982)

No.	Artefact	Site	Culture	Date, BC	Material
1	knife Gansu	Linjia, Dongxiang,	Majiayao	2750	bronze
2	knife	Jiangjiaping, Yongdeng, Gansu	Machang	2200	bronze
3	awl	Sanlihe, Jiaoxian, Shandong	Longshan	2400- 2000	brass
4	awl	Zhaogezhuang, Mouping, Shandong	Longshan		bronze
5	plate	Dahezhuang, Yongjin, Gansu	Qijia	1725± 95 1695± 95	copper
6	ring	Qinweijia, Yongjin, Gansu			lead bronze
7	awl				bronze
8	axe				copper
9	tip				bronze
10	mirror	Qijiaping, Guanghe, Gansu	Qijia		bronze
11	axe				copper

No.	Artefact	Site	Culture	Date, BC	Material
12	mirror	Gamatai, Guinan, Qinghai	Qijia		bronze
13	knife	Huangniangniangtai Wuwei, Gansu	Qijia	2000	copper
14	awl				copper
15	awl				copper
16	awl				copper
17	ornament	Qingquan, Yumen, Gansu	Huoshagou	1600	bronze
18	tube				bronze
19	nose ring				bronze
20	stud				copper
21	hammer				bronze
22	plate	Dachengshan, Tangshan, Hebei	Xiajiadian		copper
23	plate				copper
24	ear ring	Xiaoguanzhuang, Tangshan, Hebei	Xiajiadian		bronze
25	chisel	Dongxiafeng, Xiexian, Shanxi	Donxiafeng		copper
26	arrow-head				bronze
27	utensil				bronze
28	wine vessel	Erlitou, Yanshi, Henan	Erlitou	1600	bronze
29	wine vessel				bronze
30	adze				bronze

Copper Mining in China

Tonglushan mines are famous the world over. Wagner (1993: 42-49) gives the following description of the Tonglushan smelting and mines:

"Excavations at the ancient copper-mine site at Tonglushan in Daye county, Hubei, provide the material needed to shed light on this question... of iron and copper production. The Swedish geologist F.R. Tegengren visited the area in 1915 and saw ruins of old smelters and vast heaps of slag, which he estimated at several hundred thousand tons. In modern times Daye has been better known for its iron production, and Tegengren, noting that the ancient slag contains as much as 51.5% iron, concluded that iron-smelting here had been fantastically inefficient. Modern work shows that the slag is actually from copper smelting, fluxed with iron oxides.... Modern

open-pit mining operations began at Tonglushan in 1965. Numerous old timbered mine shafts were discovered, but these seem to have been ignored until the discovery of a bronze axe-head in 1973 made it clear that the shafts were much more ancient than had been thought. Excavations were undertaken by the Hubei Provincial Museum in 1974 and by the Institute of Archaeology, Chinese Academy of Social Sciences, in 1979-80.... The ancient mine shafts are at a contact zone between granite and granodiorite-porphyry, where the rock is friable and easy to mine with primitive implements. For the same reason extensive timbering was necessary to prevent shafts in the fragmented rock from collapsing. The area in which ancient mine shafts have been found measures 2 km N-S x 1 km E-W. A stratum of smelting slag extends over *ca.* 140,000 square metres; estimates of the total amount of slag, and the copper production it represents, vary. Xia Nai and Yin Weizhang estimate 400,000 tons slag, total copper production 40,000 tons, while Yang Yongguang *et al.* estimate 500,000–600,000 tons slag, total copper production 80,000–100,000 tons. A few more numbers can give an idea of the scale of operations:

- 7 ancient open-pit workings
- 18 underground workings
- 252 vertical shafts (of which 93 have been excavated)
- 8,000 m vertical and horizontal shafts
- 3,000 m wood used in timbering

“Maker’s marks on iron implements found in the mine shafts indicate with considerable certainty that the mines were worked in the first century BC. Other conventional archaeological dating methods take mining here back at least to the Spring and Autumn period. Radiocarbon dates suggest even earlier dates, as far back as the Shang period. Xia Nai and Yin Weizhang do not accept such a very early date, but they do allow the possibility that the mine was worked somewhat before the Spring and Autumn period, perhaps in the ninth century BC. Some fifty ancient smelting sites have been identified in the vicinity of the ancient mines, and at one of these ten shafts furnaces have been excavated. Conventional archaeological considerations suggest a late Spring and Autumn period date (c. sixth century BC.) for the stratum in which the furnaces were found; radiocarbon and thermoluminescence dates do not contradict this dating.... The wind-channel under the hearth serves to conserve heat and to protect the hearth from moisture; it is not connected with the interior of the furnace. Furnace operation has been reconstructed from analyses of ore, slag, and copper and confirmed through full-scale experimental simulation. It is essentially a blast furnace. Copper ore, iron ore, and charcoal were charged at the top; and a blast of air was blown in at the bottom. Molten copper and molten slag were tapped out at the bottom.... The principal ore minerals found in the ancient mine workings are:

- chrysocolla, $\text{CuSiO}_3 \cdot 2\text{H}_2\text{O}$
- malachite, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$
- azurite, $2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$
- magnetite, Fe_3O_4
- haematite, Fe_2O_3
- andradite, $3\text{CaO} \cdot \text{Fe}_2\text{O}_3 \cdot \text{SiO}_2$
- native copper, Cu
- cuprite, Cu_2O
- tenorite, CuO

"The ancient workings are all in an oxidised zone, in which sulphide ores are not encountered. A basketful of rich malachite ore was found in the mine. So it would seem that the especial value of such rich ores was recognised. However a heap of leaner ore (broken into chunks with diameter 3-4 cm) was found near furnace too. It is apparent that a mix of ores of different categories was charged. Table 1.2 (in Wagner 1993) gives analyses of two pieces of raw copper found in the ancient furnaces. These should be closely representative of the actual products of the furnaces. Note the high iron contents reported. Reduction of the various non-sulphide copper compounds to metallic copper should be straightforward in this furnace; the essential technical problem is to produce a slag with sufficiently low melting point by balancing the gangue of copper ore with an appropriate flux. The ore analyses show that silica and iron oxide are by far the most important components of the gangue, and the slag analyses indicate that the strategy adopted was to use a mix of ores of different compositions such that a slag was produced whose principal component is fayalite ($2\text{FeO} \cdot \text{SiO}_2$). In the ore analyses in Table 1.1 (in Wagner 1993) the ratio ranges from 0.23 and 7.7; thus an appropriate mix of these ores could give the required ratio in the slag.... The smelter presumably watched the conditions of the slag very carefully, and knew by experience the effect of each type of ore on the slag. In effect he aimed for an SiO_2/Fe ratio of about 0.7: if the ratio became too high he added iron ore, and if it became too low he added ores which were high to silica and low in iron. Very rich ores such as the two samples of malachite analysed in Table 1.1 (in Wagner 1933)) (*ca.* 50% Cu, 2% Fe, 3% SiO_2) do not seem to have been necessary for furnace operation, but obviously would have been desirable for reasons of efficiency. Lu Benshan and Zhang Hongli have made a calculation of the furnace charge. Assuming that the weight of charcoal charged was 50% of the weight of ore, that the blast volume was 4 m/min, that ore charged was 24% copper on average, and that recovery of copper was 95%, they calculate that production was *ca.* 350 kg per 24 hours. The simulation experiments used a much leaner ore than this: 100 kg of copper was produced in 10.5 hours; this extrapolates to 230 kg in 24 hours, and thus the calculation seems quite reasonable.... Under what conditions could a furnace like this be made to produce iron instead of copper? It seems that all that was really necessary was a higher concentration of CO in the furnace atmosphere. Reduction of copper oxides requires very little CO; reduction of Fe_2O_3 and Fe_3O_4 to FeO requires somewhat more, while reduction of FeO to metallic iron requires considerably more. Thus to produce metallic iron in this furnace with the same ore charge at the same operating temperature, all that was required was to increase the amount of charcoal charged, and possibly to reduce the blast.... One possible result of initial experiments in this direction would be "bloom iron" with low carbon, left behind in the furnace unmelted.... Smiths could work this in the usual way, or it could be charged in a cupola furnace of the type used for bronze casting, where it would be carburised and melted. Chinese bronze-casting techniques were by this time so highly developed that it would not have been especially difficult to develop the techniques necessary to cast this new metal into useful or decorative objects.... Enough is known about bloomery furnace operation to make it clear that operating a furnace of this type bloomery furnace is a practical as well as a theoretical possibility. Next question is whether it could be made to function as a blast furnace which operates continuously and produces molten iron. First, after reduction the metallic iron must remain in a CO-rich atmosphere long enough to raise its carbon content to *ca.* 4% (melting point *ca.* 1150°C). Second, a free-flowing slag must be produced. The second problem could be solved by using ores with high iron content and fairly low silica. With a loss of perhaps 20-30% of the iron in the ore, a slag could be

produced, which resembles the copper-smelting slag. The first problem is more difficult to deal with theoretically, since it involves complex considerations of reaction kinetics... Fortunately there is empirical evidence which indicates that a furnace of this size and general construction could be used as an iron blast furnace. I have elsewhere described several very small traditional "dwarf" blast furnaces used in various parts of China into modern times. Some of these are as small as 30cm high. A type of blast furnace used in southern Henan and northern Hubei had a shaft about 2 m high and 45 cm in diameter at its narrowest point. The blast input was only 1.6 m/min. The ore used was iron sand with about 65% iron and 5.5% silica. About 1.5 times as much charcoal as iron sand was charged. No flux was used, but CaO from the furnace lining may have been important in slag formation. Loss of iron to the slag was very small (*ca.* 0.2%). The hearth temperature was normally in the range 1250°-1300°C. Production was 700-750 kg pig iron per 24 hours... The structure of the Tonglushan furnaces was obviously optimised for copper smelting, and a great deal of experience would have been needed to develop an efficient furnace and operating procedures for iron smelting. Nevertheless the traditional "dwarf" iron blast furnaces are similar enough to the Tonglushan copper-smelting furnaces to indicate that molten iron could have been produced at some level of efficiency in these with only a small change in operating procedures. It may be that metallic iron was well known to the copper-smelters. A sign of incorrect operation of the furnace. Then the discovery of iron smelting would simply have been the discovery that this undesirable by-product could be useful. The technical conditions for the discovery of iron thus seem to be clarified, but economic conditions remain to be considered. Why should anyone in ancient times have wished to produce iron at Tonglushan? There was no shortage of copper ores, production per day would not have been significantly higher, and charcoal consumption would have been considerably higher. The wrought or cast iron produced initially would not have been a superior material to bronze... There is in fact no sign that iron was ever smelted at Tonglushan in ancient times. The possibility remains, however, that the same type of furnace was used in other regions where conditions were different: for example at a small copper ore deposit, which at some point was exhausted, leaving only iron ores. In order to continue supplying metal products it would have been necessary to shift over to iron production" (Wagner 1993: 42-45).

Zhu Shoukang (1982) describes the slags found in the Tonglushan mine, "The slag is fragmented, black in colour and smooth on the surface. The compositions of the slag from different strata are: 0.7 % Cu (average), 25-30 % SiO₂, 42-54 % FeO, 5-13 % Fe₂O₃, 2-6 % CaO, 4-8 % Al₂O₃, 0.2-0.4 % S. The specific gravity of the slag is 3.5-4.0, its melting point is about 1100°, and viscosity at 1280° is 2 poise. Microscopic and energy-dispersive electron probe analyses have been made, and results show that the copper in slag is metallic and sulphides, little oxide has been observed, and about 50% of the slag is fayalite (Fe₂SiO₄), about 5-10% is Fe₃O₄, the rest phase is glassy. The main mineral used in smelting in ancient times was malachite, with some cuprite, native copper, etc. The fuel was charcoal. Only a few pieces of copper were found in the site. One piece weighing 94 grams containing 93.32% Cu was unearthed at Furnace No. 3. A piece left in the hearth of Furnace No. 4 weighs 2.3 kg and contains 94% Cu and 5.42% Fe. Several undated disc-shaped ingots found in the nearby Daye Lake weigh 1.5 kg each and contain 91.86% Cu and 5.44% Fe".

Zhu (1982) says that the craftsmen in ancient China had mastered the technique of smelting copper with a blast furnace as early as two or three thousand years ago. The furnace is of a practical design and appears to have operated in a reliable way. The slag, with its low copper

content, displayed good fluidity when tapped from the furnace. It has been shown from the excavation of ancient mines that three different kinds of ores were used, of which the iron and silicon contents varied greatly, while the composition of the slag was almost identical. The silica ratio in the slag varies between 1.0 and 1.3. Moreover, the melting point of the slag is quite low (1100°C). The early Chinese technicians had a thorough understanding of the nature of different ores and had mastered the technique of controlling the slag composition by means of different fluxes. Zhu also mentions some other mining sites, *e.g.*, a site dating from the Spring and Autumn period at Linxi county in Inner Mongolia. It covers about 2.5 square kilometres, in which 47 drifts are visible on the ground surface. More than 1,500 mining implements, such as stone hammers and axes have been discovered.

With this backdrop of the Chinese archaeometallurgy, we are now in a better position to discuss the Japanese metal technology as it is basically a late derivative of the former.

BEGINNINGS OF BRONZE AND IRON METALLURGY IN JAPAN

Japan presents a unique picture of technological development. The Jomon Culture of Japan invented pottery in c. 1200 BC but bronze and iron technologies began late here, compared to China or India. Whereas in India the beginnings of copper technology can be traced to the III millennium BC, and in China to early II millennium BC, in Japan bronze and iron technologies begin almost simultaneously and just by the early centuries BC. Japan seems to have close contacts with China from a very early period, but the self-sufficient economy of the Jomon period did not require metal for its small population. Prof. Konishi (pers. comm.) explains that though Japan had started some kind of agriculture by c. 4000 BC leading to big settlements and an egalitarian social structure of their own, it avoided the so-called development of stratified society. It seems that such developments came about only with the waves of new people coming from the Korean peninsula in about 2-3 centuries AD.

Barnes (1981:38-46) explains the early interaction between China and Japan in the following words, "Bodies of water surrounding island groups such as Japan more often than not serve as a means of transportation and communication rather than as barriers or isolating mechanisms. It is not surprising then to find that the people of ancient Japan were frequently in contact with the nearby continent and that many elements in their cultural repertoire derived from the areas of modern China and Korea. In the first few centuries before and after the opening of the Christian era, ideas and objects flowed from the continent into the Japanese islands in several waves, greatly affecting the developments of material culture and the encompassing social and political systems. One of the most significant of these items was bronze. Fortunately, many magnificent bronzes (Figs. 10.5-8) of Japan—bells, mirrors and weapons—are remarkably well-preserved and provide a convenient window on the changing structure of Japan's pre-state society" (Barnes 1981: 38-46).

Describing the close interaction of Japan with China and Korea, Sahara Makoto (1987: 37-54) says, "The Yayoi period (see Tables 10.4 and 10.5) was the first in which inhabitants of the Japanese archipelago began to interact constantly with continental peoples. The civilising influences arriving from the Korean peninsula and from China were numerous and of many varieties. The ultimate transaction occurred in AD 57 when one chieftain from northern Kyushu received a gold seal from the Emperor Guangwu of the Later Han in China; this illustrates that at least one chieftain of a small Japanese polity pledged his allegiance to the Han. Bronze mirrors, jade and glass beads, carriage fixtures, iron swords, and axes - all of Former and Later Han

manufacture — plus Korean-made bronze mirrors and weapons have been excavated in great numbers as grave-goods in the northern Kyushu Island. And as we know from the dragons incised on Yayoi pots in the Kinki region, not only material objects but also many items of folklore were absorbed into Japan...”

Table 10.4 Chronology of Japanese Cultural Periods (after Akazava 1982)

Period	Temporal Span
Historic	AD 60-per cent
Kofun	AD 300-AD 600
Yayoi	
Late	AD 100-AD 300
Middle	100 BC-AD 100
Early	300 BC-100 BC
Jomon	1200 BC-300 BC

Makoto (1987: 37-54) further says that the Yayoi period was also the initial period of metal use in Japan. Bronze and iron objects appeared at the same time. At first, metal objects of continental manufacture were brought into Japan; then later, bronze and iron casting was begun there. In contrast to the iron objects first cast in Japan such as knives, axes, arrow-heads, and spear-point-shaped planes for practical use, the early Japanese-made bronze objects were bells for ritual use and ceremonial weapons such as daggers, halberds, and spears—all cast in the shapes of utilitarian bells and weapons from the Korean peninsula.

It is not always easy to determine when the import of bronze and iron in Japan stopped and local production began. Imamura (1996) says in his recent book, *Prehistoric Japan*, that there are three related problems in uncovering the origins of Japanese bronze objects:

1. The area from where bronze tools were imported.
2. The area from which the tool types and the manufacturing techniques originated.
3. The areas from which the material for domestic casting came.

He explains that the manufacturing areas of imported bronze tools were Korea and China. Korean products were imported from the end of the Early Yayoi and moulds found in Japan provide evidence that similar tools were cast in Japan soon after such imports began. Domestic production became dominant from the middle stage of the Middle Yayoi period. Around that time, Chinese bronzes such as mirrors began to be imported. Korean bronzes imported during the end of the Early Yayoi to the beginning of the Middle Yayoi include swords, spearheads, halberds, mirrors and small bells. Although they were cast in Korea, many of the original forms are found in China (Lee 1991). Spearheads and halberds had a long tradition in Shang-Zhou China. Ancestral forms of the Korean sword are seen in the Liaoning type distributed in the easternmost part of China. Korean mirrors characterised by multiple knobs developed out of a succession of forms from those with coarse line patterns. Similar forms of mirrors and ornamental plaques are seen in burials of nomadic tribes around the northern border of China. Bronze objects in Korean tradition, with the exception of mirrors, were also made in Japan. Initially made in the same form as the Korean ones, they gradually developed into unique Japanese forms. Weapons

were transformed from the thick and narrow original forms into thin and wide forms at the expense of their actual functionality. Such changes indicate that it was their appearance, rather than their efficiency as weapons that was demanded. Bronze bells became the special preference of Yayoi people and developed into cult objects, some as many as ten times larger than the Korean originals. The absence (except one fragment) of bronze axes in Japan - which might be considered mere mundane objects in this context - although present in Korea, clearly shows the purpose of the appropriation of mainland bronze (Imamura 1996).

Imamura explains that among bronze objects that played the role of cult objects and prestige goods in Japan, Chinese mirrors appear to have assumed special significance. "Mirrors that were cast and brought to Japan, probably during the Han dynasty, were passed down through many generations until finally being buried in Kofun mounded tombs a few centuries later (Kobayashi 1961). Han and later mirrors and copies made in Japan were the most important and numerous of grave goods in the early Kofun period. More than 39 mirrors, including extremely large reproductions (46.5 cm in diameter) of Late Han mirrors, were found in a tomb, at Hirabaru (Fukuoka prefecture). Opinions are divided over the date of this exceptional tomb which may be either from the Late Yayoi or the Early Kofun. There are also original forms of bronze objects indigenous to Japan. A typical item is the bronze cog-wheel ornament used to decorate shields and other objects. Its strange shape is thought to have derived from shell bracelets made from *Harpagochiragra*, a kind of seashell with long protuberances" (Imamura 1996: 168-77).

As all the raw materials for domestic casting were imported from the mainland, it is not always easy to distinguish between Korean and Japanese cast bronzes, with the exception of the local Japanese weapon forms. Moulds provide the clearest evidence in documenting what forms were cast in Japan. The discovery of early moulds such as those for narrow types of sword and spearheads from Souza and Yoshinogari (Saga prefecture) has overthrown the former assumption that such types of bronze were all Korean products. Although moulds were found from more than 60 sites, discoveries of workshops are very few. In the Yasunagata site (Saga prefecture), furnaces, moulds and bellow tuyeres were unearthed in pit-dwellings. Most of the moulds of the Yayoi period are of stone, although a few clay moulds are known as well. *Dotaku* bronze bells actually cast in the moulds unearthed at Higashinara (Osaka prefecture) have been discovered from Gahaishiyama (Kagawa prefecture), Sakurazuka (Osaka prefecture) and Kehi (Hyogo prefecture). Imamura (1996) states that such discoveries provide evidence that the casting of large bronze bells was done in a few major workshops and their products were distributed over extensive areas.

Explaining the role of bronze in the early Japanese society, Imamura says that precious bronze objects were not disposed of or left in settlement sites. Most bronze artefacts are found in graves or were deliberately buried in isolation, with no apparent relation to graves or settlements. Bronze grave furnishings for persons of high status are unusual and are seen only in northern Kyushu, although this does not mean that evidence of social stratification is found only there. Bronze ware of the Yayoi period is often found deliberately buried in places far from settlement sites and graves. Such discoveries usually occur by accident during construction or other work; thus, archaeologists rarely have the opportunity to examine the burial context. Such burials are seen extensively in south-western Japan, from Kyushu to the Chubu district. In the Kanto and other northern districts, discoveries of bronze are rare. The most intensive burial of bronze was discovered at Kojindani (Shimane prefecture) in 1984-85, where 358 bronze swords, 16 bronze spearheads and 6 *dotaku* were found from two pits on the slope of a hill far from any settlement site. Imamura

summarises the various explanations for such a burial practice by different scholars, including the following:

- That it represents the emergency concealment of bronze goods in response to an enemy attack;
- That they were normally stored underground and taken out only when necessary; so that when the cult of the bronze was abandoned, they were left in the earth;
- That they were buried as magical safeguards at the boundaries of their world;
- And finally, Ikuo Kobayashi interpreted the cases where several *dotaku* had been buried together as a situation where separate settlements which each originally possessed one *dotaku* for their respective cults had been unified, and thus buried their *dotaku* together.

A typical *dotaku* from Hatsu Katayama site (Nara prefecture) of the late Yayoi period is shown in Fig. 10.7. A later functional example of bronze bell from Otsu, dating to eighth century AD is shown in Fig. 10.8.

On the problem of *dotaku* burials, Makoto (1987: 54) says, "The bronze bells (Fig. 10.7-8) are one of several kinds of bronze articles characterising the Yayoi period. They originally functioned as real bells, producing a sound by a clapper hitting an inside rim when suspended. However, as time progressed, the bells became larger in size and excessively ornate in decoration.... Tanaka Migaku has respectively distinguished between these older and newer bells as 'bells to listen to' (Styles I-III) and 'bells to look at' (Style IV) because the latter seem to be more ornamental than functional.... Bronze bells are seldom recovered from settlement sites or burials but usually appear to have been deliberately deposited in pits specially dug in hill slopes some distance from the villages. There are cases of single deposits and deposits containing several bells. The latter are probably 'hoards' in the sense of the word as it is used by European archaeologists".

Describing the socio-economic impact of metallurgy, Sasaki says that it is possible to detect the changes in the role of bronze weapons in the Yayoi society, as they were adapted in Japan. When these weapons were first imported from Korea, some of them had already lost their original function as weapons. They became the symbols of wealth for the Kyushu chiefs. As time passed, they developed into objects for communal rituals. Outside of Kyushu, it appears that bronze weapons had always been used as ritual paraphernalia because very few of them so far have been discovered in a burial context. In any case, after the adoption of bronze metallurgy and the resultant domestic manufacture of the bronze weaponry, their function became purely ceremonial all over Japan.... Another type of bronze objects, which shows a similar pattern of adaptation, is *dotaku*. The ancestor of the Japanese *dotaku* can be traced back to a small Korean bronze bell, like ones discovered at the Ipsil-ni site. While a Korean bronze bell lacks any decoration on the body, fins, and has only one hole resulting from chaplet which held the outer and inner moulds separate on each side, a Japanese *dotaku* is characterised by decoration, fins, and two holes resulting from chaplet on each side. The size of the Japanese *dotaku* is considerably larger, too.

In Japan, *dotaku* were ritual paraphernalia from the beginning. A great majority of them have been discovered on hillsides far away from settlements. Since none of them have been discovered in a burial context, this seems to indicate that the *dotaku* were owned communally. Some of the large *dotaku* have pictures related to agriculture and hunting, which suggests the context of the rituals in which they were used. Whereas in the Kinki region, the *dotaku* developed into large ceremonial objects, in Kyushu it was the bronze ceremonial weapons already discussed

which became the major ritual paraphernalia. Findings from the phase IV or V context in Kyushu show only small Korean bronze bells and some moulds for small and early types of *dotaku*. This suggests to Takesue that *dotaku* were used for rituals in private households, while the over one-metre high *dotaku* of the Kinki and Tokai regions were used for larger scale communal rituals.

Sasaki (in press) has recently done a study of Japanese archaeometallurgy and its societal impact. It is a very recent and important study and therefore we would like to quote extensively from this source (the references quoted below are given from the Sasaki's note and are mostly from Japanese sources).

Sasaki says that the Japanese archaeologists agree that there were five different peaks of acceptance of metal objects from Korea and China. The first peak occurred in Kyushu in the Yamanotera and Yusu contexts, and with it came methods of rice cultivation. A bronze arrow-head and a copper chisel discovered at the Imagawa site in Fukuoka prefecture are representative of this peak. Okazaki and Kondo T. suspect that the bronze arrow-head is a reworking of a Liaoning style sword, similar ones of which were also discovered at the Songguk-ri site in Korea. This finding, together with the discovery of semi-subterranean houses identical to those at the Songguk-ri site, led Kondo T. (*ibid.* 301) to believe that this peak is an extension of the early bronze culture in Korea (Kim W.-Y. 1984: 80.1), represented by the Songguk-ri site. Another important aspect related to this peak is the accompanying evidence of the iron tools.

Sasaki mentions that the second peak came to Japan from Korea at the end of phase I (the early second century BC). A slender sword, halberd, spear, and Korean geometric mirror are characteristic of this peak. In terms of the quantity and variety of the bronze objects, we can finally speak of the "bronze culture" in Japan from this time on (Shimojo 1985: 109; Kondo 1984: 301). He points to its similarity to the Ipsil-ni assemblage, which represents the Late Bronze Age in Korea, (c. 300-100 BC). This similarity may have been caused by immigration from Korea facilitated by a population increase resulting in the development of agriculture in the Late Bronze Age (Kim 1984: 112). These slender swords and spears are classified into the shorter and more practical type I, and the longer and less practical type II, which lacks strength as a weapon. In Korea, the type I bronze weapons are dated to the early half of the Late Bronze Age (third to second century BC) and the more "ceremonial" type II to the later half (first century BC). In Kyushu, the type I bronze weapons appeared at the end of phase I (middle second century BC), and the type II weapons sometime in phase II (the late second century to the early first century BC). This tendency of importing weapons for ceremonial or ritual purposes rather than for warfare continued into phase III (the first century BC).

The third peak of importation, according to Sasaki, is dated to the later half of phase III and is characterised by Early Han mirrors, a glass *bi*, and other gold-copper ornaments. Large iron weapons, such as swords accompany this entire peak and the following peaks and spears, probably taking over the place of non-functional bronze "weapons". Xin coins and Late Han mirrors were imported to Japan in phase IV as the fourth peak.

Sasaki says, "Finally, at the end of the Yayoi period and the beginning of the Kofun Period (the third century AD), Chinese bronze objects of the Three Kingdoms Period (AD 220-80) flooded into Japan. A representative example is a bronze mirror with a thick edge believed to be manufactured in Wei".

While still importing numerous bronze objects, Sasaki says, "During the Yayoi Period, the Japanese also began to manufacture their own bronze objects modelled after the Korean or Chinese originals. These Japanese copies clearly illustrate how Japanese adapted foreign material

culture....When bronze weapons were introduced, they were treated either as symbol of wealth or authority or as communal ritual paraphernalia. To increase the visual impact, these objects were made larger and consequently less functional. Relying on this fact, the bronze weapons - both functional and ceremonial - are classified into four general categories: slender, medium-slender, medium-wide, and wide. Each category is further divided into a few classes depending on the presence or absence of certain features. Chronologically, the weapons change from the slender type to the wide type”.

The earliest evidence of the production of bronze weapons comes from present-day Saga prefecture in Kyushu. Archaeologists discovered fragmentary moulds of a slender spear and a slender sword. Another Yayoi site, the Soza site, has recently yielded a fragmentary mould of a slender sword. These moulds are associated with early phase III pottery. These discoveries are significant in two respects: 1). The production of bronze weapons in Japan may well predate phase III in Kyushu; and 2) some slender weapons, which used to be considered Korean-made, were in fact manufactured in Kyushu.

According to Sasaki, Iwanaga gives two possible reasons why slender spear and sword similar to those of Korea were made in Japan: (1) They were made by Korean immigrants in Kyushu or (2) the production was commissioned by Yayoi people, but perhaps as a result of the unequal power relations with Korea at that time, they could not dictate their own taste or preferences as to the final product. Nonetheless, the production of medium-slender bronze swords and spears started very soon after Japanese began to import Korean bronze weapons at the end of phase I or phase II. When the phase III is further divided into four sub-phases, from 1 through 4, production of slender swords and spears in Kyushu began in phase III-1; medium-slender swords in phase III-2, medium-slender spear in phase III-3, and medium-wide spear in phase III-4.

In the beginning, these bronze weapons were buried in tombs, following the practice of the Bronze Age Korean burials. This means that the bronze objects were treated as symbols of individual wealth because of their rarity. Among spears, swords, and halberds, the spears were most treasured. Both at the Mikumo site and Suku-Okamoto site in Fukuoka, spears were placed in large jars used as coffins, and swords and halberds were placed outside of the jars. In addition, while slender bronze swords were widely distributed in small quantities in the western part of Japan, slender spears were concentrated in the present Fukuoka and Saga prefectures. Chiefs who presumably imported these bronze weapons from Korea or controlled the production of them kept the most valuable spears near their headquarters and distributed the less important swords and halberds as gifts (Sasaki in press).

According to Sasaki, the communal rituals utilising bronze objects began when medium-slender weapons appeared in Japan. The paraphernalia used for such rituals was carefully buried far away from settlements or cemeteries. A good example of this is the Kojindani site in Shimane prefecture where 358 medium-slender swords as well as six *dotaku* and sixteen bronze spears were discovered. In addition to the rise of communal rituals utilising bronze objects, iron weapons also gradually became common, some of which were placed in tombs. Nonetheless, during the later half of phase III and phase IV, some of the most powerful chiefs who were buried in Jar D at Suku-Okamoto, Jar 1 at Mikumo Minamikoji, and Jar 10 at Tateiwa-Hotta, could still be accompanied by medium-slender weapons when they died. As time passed, however, the tendency to utilise bronze objects for communal rituals became stronger despite the wish by wealthy chiefs to keep them as personal belongings. Indeed, considerably fewer medium-wide and wide “weapons are discovered in burial contexts in the later phases. Since the chiefs were no longer distinguished

by their possession of the bronze weapons, they had to maintain their power and authority by becoming the master of the new communal rituals.... An example of this can be found in the depiction of a woman chief toward the end of the Yayoi Period in a Chinese dynastic history. It is very suggestive: the people agreed upon a woman for their ruler. Her name was Himiko. She occupied herself with magic and sorcery, bewitching the people". The increasing power and authority of certain chiefs seems to be reflected in the ever-larger number of buried objects found in later sites. The quantity found implied the control over the resources of at least some communities.

Higuchi (1986: 124) also says, "Mirrors constituted one of the most popular items symbolising wealth and power, and they seemed to appeal particularly to Japanese tastes. Both imported mirrors and those that were locally made had an effect on the development of Japanese craft manufacture. This great interest in mirrors declined during the later Kofun (sixth century AD) but regained momentum in the Nara period (AD 645-794) when Chinese Tang mirrors were imported. In the mid-fifth century, gilt-bronze accessories were imported from Paekche and Silla on the Korean peninsula, among them crowns, decorated shoes, earrings, metal belt ornaments, as well as decorated horse bits, straps, and saddles. Some of the horse gears show signs of originating from the horse-riding tribes of the north. A typical example is the horse stirrup excavated from the Otani mound burial in Wakayama. We believe that for this period most of the stirrups and other horse gear were still used for ritual purposes only. At some point during the fifth century, *sueki* - a hard-fired grey pottery - was introduced into Japanese culture. This pottery is without doubt closely related to the grey stoneware of China, as well as to the burial stoneware of Silla".

Sasaki reports that a fragmentary mould of the earliest type of *dotaku* has been discovered at the Kaide site in Kyoto prefecture in the context of phase II pottery (the late second century BC). Archaeologists in Japan suspect that the production of *dotaku* may have begun in phase I in the Kinki region. Iwanaga also states that if we consider the Korean geometric mirror as the origin of the surface decoration for some *dotaku*, the beginning of the production of *dotaku* in Kyushu could be dated back to the end of phase I.

About the mirrors, Sasaki says that the change in the role played by bronze mirrors in the Yayoi and Kofun society followed a similar pattern to the two discussed above. The jar burials of some chiefs during the Yayoi Period yielded a considerable number of mirrors, such as thirty-five at Mikumo, twenty or twenty-two at Suku-Okamoto, and ten at Tateiwa-Hotta. This is in marked contrast to the Chinese and Korean cases. For example, at the un plundered Tomb No. 5 of a royal consort at Yinxu, which has yielded 468 bronze vessels, archaeologists have discovered only four mirrors. This difference in quantity clearly indicates that in Japan mirrors were used for more than simply reflecting one's images. In Korea, geometric mirrors have been discovered in men's burial sites and often in association with a sword. Japanese cases are distinguished from the Korean by the large quantity of mirrors found in each tomb — sometimes as many as thirty-five! A prominent example of a Japanese site of this kind is the Tsubai-Otsukayama Kofun where excavators discovered thirty-three Chinese bronze mirrors (four Late Han, twenty-eight Wei, and one impossible to identify). Kobayashi began to compile Kofun Period sites which yielded mirrors cast from the same moulds. The chart by Kobayashi tends to suggest that the chief buried in the Tsubai-Otsukayama Kofun distributed extra mirrors to local chiefs. Kobayashi further hypothesised that by the time of the late Shonai or early Furu phase (the end of the third century AD), Japan had achieved a state-level society with headquarters in the Kyoto-Nara area. Sasaki

says that Kobayashi's hypothesis has been criticised by Wang who believes that these Wei Dynasty mirrors were in fact made in Japan. Sasaki believes that sharing mirrors cast from the same moulds represents a sort of symbolic or ritual relationship, if not political. Even if these mirrors were indeed made in Japan, this would still hold true.

Table 10.5. Chronology of Japanese archaeology with cultural traits
(after Imamura 1996)

period	Date	Derivation of period name	Pottery	Ground stone tool	Bronze tool	Iron tool	Agriculture	Tomb of chief	Document	No. of sub-division
Pre-ceramic (Palaeolithic)	10,000 BC	Pre-ceramic	-	+	-	-	-	-	-	2
Jomon	10,000 to 500 BC	Cord mark	Jomon type	+	-	-	?	-	-	6
Yayoi	500 BC to AD 300	Site name	Yayoi type	+	+	+	+	+	Recorded in China	4
Kofun	300 to AD 700	Type of tomb	Haji(ki) type	-	+	+	+	+	Recorded in China	2 or 3
Historical	AD 700	Historical	Haji(ki) type	-	+	+	+	+	Contemporary record	

Source of Bronze

Imamura gives the lead isotope analysis data to determine the source areas of lead, which is added to copper alloy. This method is based on the fact that the ratio between three kinds of lead isotopes is constant over a large area beyond the immediate locations of a mine, with changes apparent only beyond extensive areas. The analyses indicated that the plots of Korean weapons and mirrors were identical to lead specimens from many present-day mines in Korea. This clearly shows that Korean material was used for such products. On the other hand, Chinese mirrors discovered in Japan correspond to the isotope ratio of lead presently excavated from northern China. Bronze cast in Japan clearly demonstrates that bronze material from both Korea and China was used. The source materials used for producing *dotaku* bells in Japan are known to have changed over time. Early specimens indicated that Korean material or melted Korean bronze objects were used. *Dotaku* of the middle type fall within the range of lead isotopes from northern China, with those of the late type concentrated in a very small area within the range of northern Chinese lead. Not only are the ratios of lead isotopes consistent, but also the composition of copper, tin and lead is very constant for these late bells. Hisao Mabuchi, who analysed the material, argues that precisely compounded bronze alloys in the form of ingots must have been imported from northern China.

Socio-economic implications

Sasaki believes that the impacts during the Final Jomon and phase I Yayoi Periods were minimal. Rice cultivation, along with the opening and maintenance of rice paddies and irrigation systems, did not entail a larger labour unit than that of the earlier Jomon Period when people relied on gathering and hunting for their subsistence. This size of community remained to consist of four or five households throughout the later Jomon Period and the beginning of the Yayoi Period.

The situation, however, began to change towards the end of phase I. As the productivity of rice rose, the population increased. To cope with this increase, the people had to open up more rice paddies on the alluvial plain. This required co-operation among communities to build long-distance irrigation ditches. Co-ordinating the activities of a large number of people required leadership. At the same time, the need to increase productivity pushed communities into competition for control of the alluvial plains, and this would lead to differences in wealth. Such internal and external differences in responsibility and wealth began to be reflected in burial goods in Kyushu.

Some chiefs buried bronze mirrors and weapons in their tombs. These bronze objects were the symbol of their wealth and status. By that time, the members of their communities may well have respected the chiefs, but they still needed some concrete objects to symbolise the distinction between themselves and the rest of the population. In phases II and III of the Yayoi Period, they did not have sufficient power and wealth to build a palace or an enormous burial mound or Kofun. They did, however, have some wealth with which to purchase exotic bronze objects first from Korea, then from China as well. Later, when they could indeed build Kofun, bronze mirrors played a role in symbolising relationships and hierarchy among the chiefs. In this sense, the chiefs' ownership of bronze objects helped create a social class separate from the rest of the population.

At the same time, bronze objects also began to be used in the communal rituals to cope with natural disasters and to increase the productivity of their crops. For these ritual purposes, people would bury the bronze objects in places such as hilltops, which could be viewed from many different communities. These communal rituals would have helped unify the communities as communal co-operative construction projects would have. As these communal rituals became more important, it became more difficult for the chiefs to maintain exclusive ownership of the bronze objects, and the chiefs in Kyushu tried to justify their position by transforming themselves into masters of the ceremonies. In other western regions of Japan, the chiefs may well have been the masters of these rituals from the beginning.

As the demand for the bronze objects escalated, people had to mass-produce them. The Kojindani discovery typifies the demand. Chang (1980a: 46) states that "The large-scale production of such technologically sophisticated bronzes as these [Shang and Zhou bronze vessels] must have required multistage operations by many kinds of specialists, who must have been organised and supervised by the state". Although the Japanese bronze objects were not as sophisticated as Shang (Figs. 10.4) and Zhou bronze (Fig. 10.3) vessels, some degree of co-ordination and specialisation of labour was necessary to manufacture a large number of bronze objects. Sasaki thinks that agriculturists' experience of co-ordination and co-operation of activities made this possible.

While the greater part of the population did not have access to bronze objects in their daily lives, iron tools, despite their scarcity, were essential for rice cultivators as it was very difficult

to construct vital irrigation ditches on dry plains and to sharpen the edges of wooden agricultural tools without iron edge. Kurosaki notes that at the Dainakanoko-Minami site in Shiga prefecture, while both unfinished and finished agricultural tools were discovered, only finished heavy-duty tools were present. He interprets that although the manufacture of wooden agricultural tools took place at local communities, the preparation of heavy-duty construction tools, which needed to be sharpened by iron blade, was carried out only at designated communities, where influential chiefs were likely to have resided. He further hypothesises that chiefs monopolised the ownership of iron tools necessary for opening land or for sharpening the edge of heavy-duty wooden tools, and rented out these iron tools as necessary. In other words, the chiefs manipulated the scarcity of iron supply to strengthen their positions.

The distribution centres of iron tools are presumed to be located in the northern Kyushu and Kinki regions where metallurgical sites are sometimes discovered. Nonetheless, iron tools were also essential for people in the eastern part of Japan who depended on rice for subsistence. Amakasu speculates the presence of institutionalised exchange networks, which provided the people in the east with the iron tools, which were necessary to keep their rice production going. In this sense, the scarcity of iron may well have facilitated the development of institutionalised trade networks. Japan's adoption of rice cultivation for subsistence, and of bronze and iron for technology facilitated the development of a social class of chiefs who exercised control over the rest of the society.

SUMMARY

China is a huge country and therefore the possibility of multiple origins of metallurgy can not be ruled out. Unlike the Indian metallurgy, it has a distinct monumental and elitist character. The massive vessels, statuary, and ornate mirrors are obviously symbols of power of the elite. The Japanese metallurgy, on the other hand, is a late transplant from China and Korea. Both copper and iron metallurgy arrived together from China just a few centuries before the Christian Era. Both *dotaku* and mirrors unmistakably show their elitist and ceremonial character. Though the latest calibrated AMS dates suggest that the earliest ceramic technology in Japan goes back to c.16000 BP, the Neolithic economy of the Jomon culture continued virtually unchanged, till the Yoyoi period when metals and urbanisation were transplanted from China.

In the next chapter we will discuss iron technology and its role in early urbanisation processes.

CHAPTER 11

IRON

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INTRODUCTION

This book is focused on bronze and therefore this chapter on iron has to be brief, though we have tried to cover the most important aspects.

Since iron is better, stronger and more abundant, once it came on the scene, it gradually took over. But the use of iron minerals goes back into prehistory as explained by Denise Schmandt-Besserat (1980: 127-50). She explores the earliest uses of iron minerals (ochres) in prehistory and concludes that ochre appears to have been associated with human industries with *Homo erectus*, now dated to 1.6 million years. From the Mousterian period on, c. 700,000 BC, it recurrently appeared among the human habitats. "From 30,000 to 11,000 BC a great increase in the number of caches of ochre, mortars and grinders for its preparation, and accumulation of processing debris around the campfires indicates that ochre was playing a predominant role in human society during the Upper Palaeolithic period. The naturalistic and geometric paintings on cave walls, blocks, pebbles, and bones cannot account for the great amount of colouring matter processed by Palaeolithic man. We do not know what the main uses of ochre were at the time. We have to postulate that they involved manifestations that did not survive to our age and may have included body paint, tanning and colouring of skins and furs for the superstructure of the tents and the bedding and garments, and the decoration of objects in perishable materials such as bark, wood, wickerwork, and vegetal fibres" (Schmandt-Besserat 1980: 127-50).

She thinks that the bright colours of ochre (yellow-red) must have had symbolic meaning for early man through the ages. "This sense is given credence during the Mousterian (c. 60,000

BP) when ochre became part of funerary rituals and was included as lumps among the objects thought to be propitious for the dead in the next life. We lack any insight into the prophylactic or beneficial qualities it conferred, and the reason for instance that red pigment seems to have been preferred in the Palaeolithic paintings of the Pyrenees, while black predominated in the Dordogne. In Neolithic times ochre penetrated the potter's workshop. Red decoration on pottery is almost as old as pottery itself, and was being used for overall slips or designs on parts of the vessels. Under both oxidising and reducing atmospheres, the pigment alternately turns red, brown, or black" (Schmandt-Besserat 1980: 127-50).

She surmises that the search for pigments did familiarise man with the various appearances of the main iron ores and the location of their sources and helped him to develop the habit of collecting and storing them. The goal of achieving better and brighter colours by calcination may well have led toward the process of smelting. She says that man's natural attraction for colour sensations led to important steps in the evolution of technology. The use of pigments may be considered as the lengthy and necessary preliminary stage leading to metallurgy.

Wertime has explained the pyrotechnologic background of the advent of iron technology (Wertime 1980: 1-24). He says that iron's fate had hung in the balance for several thousand years after Paphlagonian tribesmen had evidently learned to smelt it consistently from its ores. The acceptance of the new metal was thus a matter of opportunity, costs vis-a-vis both bronze-age and stone-age materials, determined by a combination of social, economic, technologic, and ecologic circumstances. Wertime elucidates the wide ranging effects of the advent of iron. The appearance of such drastically new and disruptive technologies thus can be seen as the concomitant of a critical stage involving not just the carburisation of iron to make steel but the shifting fortunes of agriculture and human populations in the Eastern Mediterranean; the interruption of trade in copper and other metals; the movement of iron-carrying tribes from the Black Sea north, south, east and west; and possibly the first effects of a declining supply of charcoal and other fuels in the area.

There are positive merits in the use of iron over bronze and therefore iron eventually took over. Wertime (1980:1-24) has enumerated six qualities of iron.

1. The first quality of iron is its sheer abundance. By an 'iron catastrophe' it probably melted and sank to the core of the Earth early in the history of this planet, becoming the planet's dominant element.
2. The second is the ferromagnetism, which it shares with nickel and cobalt.
3. The third is its high energy as a transition metal, owing to the quantum levels of its atom. This it also shares with cobalt and nickel.
4. The fourth quality is the ability of iron to shift from the ferrous to ferric form and back under differing states of oxidation and reduction.
5. On heating, iron has the capacity to change crystalline form (from a body-centred cubic to a face-centred cubic lattice), which allows it to be quenched into a hard steel, endowing it with special structural and aesthetic qualities.
6. The last important quality of iron is that it accepts carbon and other materials into an interstitial solution.

Wertime explains that iron-silica and calcium carbonate (along with soda) were closely interconnected in furnace operations at temperatures that stayed consistently above the melting point of copper (c.1100° C). Although the kilns or furnaces may have come from widely separated

sources (the pottery kiln from the cooking hearth and the lime kiln from the fire setting of stone, for example), what emerged during the Bronze Age were four major interwoven pyrotechnologic products: terracotta, iron, glass, and cement.

The consequences, Wertime states, of an interactive furnace pyrotechnology for civilisation were enormous. "What stands out ... is the interconnectedness and massiveness of the thrust toward a literate, trading and communicating, road-building and seafaring, urban, pyrotechnologic civilisation emerging in the Fertile Crescent and Eastern Mediterranean.... In this context the case for the diffusion of iron worldwide from an Eastern Mediterranean source becomes almost overwhelming. Glass is known to have spread both east and west from the Levant. The pyrotechnologic precedence of the ancient Near East seems beyond doubt" (Wertime 1980:1-24).

Waldbaum (1980) has traced the archaeological and literary evidence of meteoritic iron in the Middle East. Terrestrial iron seems to have been no less used in early artefacts than was meteoritic. The Stone Age cultures whose appetites seemed to have been most whetted to the use of meteoritic or native iron were those which entered the native metal stage and never got beyond it.

IRON ORES

Magnetite: a black magnetic stone; Mohs hardness 5.5 to 6.5; specific gravity 5.4; containing 72.4 per cent iron when pure; it is Fe_3O_4 .

Haematite: a sesquioxide of iron, with about 70 per cent iron when pure. Specific gravity 5; Mohs hardness 5 to 5.5; chemically it is Fe_2O_3 .

Limonite: a hydrated iron oxide; hardness 4 to 5.5; specific gravity 2.7 to 4.3.

Goethite: it occurs in lateritic soils; specific gravity 3.3 to 4.3.

Siderite or Chalybite: Chemically it is FeCO_3 ; with only 48.3 per cent iron when pure.

Pyrite: Chemically FeS_2 ; with only 46.5 per cent iron.

Gossan: it is the multi-mineral red iron cap on an exposed sulphide deposit whose chalcopryrite (CuFeS_2) has oxidised, and iron leached out.

Let us now see the difference between wrought iron and steel.

WROUGHT IRON

Iron has been made for at least 4,000 years. The discovery may well have been accidental and made in several different places over a long period (Gale in McNeil 1990). At all events, iron-making had spread to Europe by about 1000 BC from the Middle East, where it apparently began much earlier.

The product made by the early workers in iron was wrought iron. Wrought iron can be shaped by hammering it while it is hot and if two pieces at the right temperature are hammered together they weld into one piece. It is possible to melt wrought iron but is of no practical value, so it was never melted in practice. The iron was converted, or reduced, directly from the ore in what is therefore termed the direct reduction process.

The early equipment used to make wrought iron was as simple as the metal itself, consisting of a small furnace, heated by charcoal, and called a bloomery. Foot-operated bellows were used to blow the charcoal fire and some tongs to hold the hot metal while it was forged into shape. Bloomeries varied in shape and size, though they all functioned in the same way. They were made of clay, which would resist the heat of the fire. Charcoal was lighted inside the bloomery

and then, while a continuous blast of air was kept up by the hand or foot bellows, more charcoal and some iron ores were fed in by hand through a small aperture in the top. As the oxygen in the ore united with the carbon of the charcoal it became a gas, which burned off at the top of the bloomery as a light blue flame. After a few hours all the oxygen had gone from the iron ore, and a small spongy ball of iron was left. The bloom from which the bloomery took its name remained. Then the front of the bloomery was broken open and the bloom was raked out and taken to an anvil for hammering to whatever shape was required.

Wrought iron may be defined as a soft, ductile, and fibrous product with small amounts of slag and largely free of carbon. A mild steel begins at about 0.08 per cent carbon. At 0.2 to 0.7 per cent carbon, iron becomes steel. Cast iron has up to 4% carbon and is brittle by nature. The absorption of carbon lowers the melting temperature of the iron and predisposes it to be tapped in liquid form as a pig iron. This was the dominant initial smelted product when the blast furnace came into vogue in c.AD 1400.

Before AD 1400, except in China and Africa, the extant smelting conditions produced only a spongy iron low in carbon and much interspersed with slag. Mainly because they rarely could attain the melting point of the iron, which at 1540°C is substantially above the melting point of the slag. Much heating and forging were thus necessary to extract a workable metal (Gale 1990).

STEEL

If the right amount of carbon is added to iron, the metal is capable of being hardened to any required degree. This fact was known some thousands of years ago. It was discovered that if a piece of iron were heated in contact with charcoal, the surface became quite hard, a process now called casehardening. The trouble was that only a very thin skin - as little as a few hundredths of a millimetre - was hard. When this wore off, as it would in time, the softer part of the iron was exposed (Gale in McNeil 1990).

By the early years of the 18th century it was well known that the longer iron was heated while packed in carbon, the deeper the carbon penetrated into the iron giving a thicker hard skin. The process was known as cementation.

Wertime suggests that since lead smelting preceded iron by many centuries, the smelting of iron could accidentally have been discovered in a lead smelting furnace and later developed for its own sake.

ORIGINS OF IRON TECHNOLOGY

Wertime asserts that the first systematic pursuit of iron and steel technologies occurred in Anatolia. The historical metallurgy began by using the black iron sands of the Black Sea. If high nickel steels of smelted sands thus resulted, Wertime says, "We shall have to reappraise all so-called meteoritic iron for its actual origins". Anatolia was not without its own splendour in innovative metallurgy judging from the smelted iron dagger of Alaca Huyuk set in a bronze handle.

I have to enter a caveat here. Killick (pers. comm) informs, "Prehistoric smelting of the black sands of Macedonia has been thoroughly investigated by Effie Photos (see E. Photos *et al.* 1984:113-20). These are magnetite/ilmenite/rutile sands - the titanium goes into the slag. The putative addition of nickel arsenide to iron to make steel is unproven and seems to me highly unlikely. Far more probable is the smelting of nickel-rich bog iron ores or laterites. The geochemistry of nickel is very similar to that of iron, and hence nickel can be deposited wherever

iron is. The fact that this is not common is attributable to the scarcity of nickel-rich source rocks — the only viable candidates are ultrabasic intrusives". Nickel rich laterites are an important source of nickel today in New Caledonia, where they are developed over peridotites, and in Sulawesi, where there is good evidence that many of the *kris* blades were made from smelted nickel-rich iron (Ben Bronson 1987:8-15).

About early meteoric iron, Moorey (1994:279) has made some important observations, "Vaiman (1982) argued that there are references to meteoric iron in Sumerian texts from late in the fourth through to the third millennium BC and that the appearance of the terminology, first documented at the end of this period, coincided with the appearance of smelted iron. However, present evidence for iron terminology both in ancient Egyptian (Harris 1961: 60) and in Hittite (Kosak 1982: 199; 1986: 125-26) indicates that specific references to 'iron from heaven' and 'iron of (or from) the sky' do not appear until the second half of the second millennium BC, in the Late Bronze Age, by which time iron from copper or lead smelting or smelted intentionally from iron ores was already current. Even if some of Vaiman's early references indicate iron in Sumerian, and some at least are unacceptable on philological grounds (*cf.* Muhly *et al.* 1985: 175), it is more likely to be a generic term leaving the question of origin open. A passage from the Sumerian *Lugalbanda Epic*, in a copy of the Old Babylonian period (c. 1650 BC), is read in a recent translation by Hallo (1983: 176) as distinguishing an axe of meteoric iron from a thigh- or hip-dagger of terrestrial iron. However, the first phrase turns on a restoration in the text which, as it stands, refers only to precious metal generically not specifically; indeed, if Hallo's restoration is correct it could be referring to *annaku* (tin! lead). The second phrase speaks simply of 'iron' (J. A. Black: personal communication). At present the history of terms for iron in Sumerian and Akkadian does not firmly indicate whether a special terminology for 'iron from heaven' preceded or succeeded the regular smelting of iron ores.

"Desch (1928) identified fragments of early iron from Mesopotamia as of celestial origin through bulk chemical analysis of their corrosion products on the assumption that a high nickel content, comparable with that in actual meteorites, was alone a safe distinction between iron of celestial and iron of terrestrial origin.

"This is now known not to be so. Moreover, surface indications of nickel are likely to be misleading, since corrosion will alter the Fe/Ni ratio. Today determination of the origin of nickel-rich iron, whether celestial or terrestrial, depends on a variety of analytical and metallographic techniques to determine the structure of the metal as well as its body composition. The presence of nickel, which will anyway be reduced in the process of smelting nickel-rich terrestrial iron ores, in an iron artefact can only imply a meteoric origin if the original Widmanstätten structure is also present (*cf.* Photos 1989; Rostoker and Bronson 1990: 201—3), as in an iron ball or pellet from level II at Tepe Sialk in Iran, in the fifth millennium BC (Ghirshman 1939: 206).

"The occurrences of early iron objects in Mesopotamia said to be of meteoric origin on the basis of high nickel content now need to be re-examined. They are a fragment found between levels D and E of the Anu Ziggurat at Uruk, late fourth millennium BC (Heinrich, in Noldeke *et al.* 1937: 53), rusted fragments of uncertain purpose (?dagger knife) from RT 580 at Ur and pieces from Tell al'Ubaid (*cf.* Woolley 1934: 293; analyses by Neumann: 10.9 per cent nickel), of the mid-third millennium BC.

"Piaskowski (1988) has argued that the famous Chalybean iron, produced in northern Anatolia from iron-bearing river sands, which looked more beautiful than other iron and did not get rusty, according to pseudo-Aristotle, was a high-nickel iron. Piaskowski has consequently suggested that

'most ancient iron implements considered until now by the historians of metallurgy as made of meteorites, were really produced in the iron smelted from the ore as early as in 3000-2000 BC by the tribe of Chalibes ...' (Piaskowski 1988: 45). This challenging hypothesis needs to be substantiated by wider investigation of the high-nickel iron ores of Turkey. The only substantial object so far scientifically tested that might well be made of high-nickel iron from an Anatolian source is the Late Bronze Age iron blade (2.5 per cent nickel) of an axehead with a zoomorphic bronze shaft-hole found at Ras Shamra, Ugarit (*cf.* Waldbaum 1980: 76 nn. 7, 22; Richardson 1943)".

Vibha Tripathi has also pointed out the possibility of the use of the river sands from the Himachal Pradesh rivers (India) for iron smelting.

Keeping in mind the above reservations, let us now briefly trace the earliest occurrences of iron in West Asia with Jane Waldbaum.

Waldbaum (1980: 69-94) says that to date, fourteen iron objects have been recorded at only four sites dating before c. 3000 BC (Table 11.1). The objects are a four-sided instrument from grave A at Samarra in northern Iraq, dated c. 5000 BC, with a preserved length of c. 4.30 cm; three small, nearly spherical balls from a period II habitation level at Tepe Sialk in northern Iran, c. 4600-4100 BC; nine beads from pre-dynastic graves 67 and 133 at El Gerzeh, and a contemporary ring from grave 1494 at Armant in Egypt, all c. 3500-3100 BC. The Sialk balls were described as "very hard and heavy" and were apparently used as polishers. The Samarra piece, the Sialk balls, and one of the Gerzeh beads were analysed for nickel. The Samarra piece was smelted; the others were meteoritic (Waldbaum 1980: 69-94).

Table 11.1 Meteoritic and smelted Iron before c. 3000 BC from the Near East and Eastern Mediterranean (after Waldbaum 1980)

	Meteoritic	Smelted	Not analyzed	Total
Iran	3 ("balls")			3
Mesopotamia		1 ("tool"?)		1
Egypt	1 (bead)		9	10
Total	4	1	9	14

From the Early Bronze Age, c. 3000 - 2000 BC, the pieces from Uruk and Ur proved to be meteoritic (Ur, 10.9% Ni; Uruk, %Ni unstated); those from Tell Asmar and Chagar Bazar contained no nickel and are therefore smelted.

Summing up Waldbaum says that up to the end of the 3rd millennium BC iron was being used sporadically and treated as a precious material. Weapons and tools are clearly ceremonial in function, combined with gold and other precious materials as at Alaca and Dorak, and not intended for daily use. Geographically the iron is so far limited in distribution to eight rather scattered sites in Mesopotamia, and six in Egypt. Chronologically, most of the material falls in the second half of the 3rd millennium - the Early Dynastic III period in Mesopotamia, the Early Bronze III period in Anatolia, and Fourth Dynasty or later in Egypt. Both meteoritic and smelted iron was in use simultaneously during this time.

Thus it seems that in the early 2nd millennium iron was still used as a precious and rare material associated with royalty or the temple, or buried with other valuables in tombs.

Waldbaum thinks that the Hattusilis' letter may indicate a certain degree of Hittite control over the production of smelted iron, which was then shipped out as raw material to the correspondent, presumably the king of Assyria. Use of iron in Hittite Anatolia does not differ markedly in kind from that known in other regions during the Bronze Age. According to Waldbaum, black-smithy and bronze-smithy were not yet strictly separated. Early experiments with smelted iron as a precious metal and the widespread availability of iron ores naturally led metalworkers to turn to iron when decreased trade and shortages in supplies of tin drove the price of bronze too high. A transitional period of more intense development of iron resulted in the production of greater number of implements that were comparable to bronze in cost and efficiency. By the end of the 10th century BC, in the Eastern Mediterranean, the full Iron Age was attained. Iron was now being used for many of the daily needs of life. Muhly (1980:25-68), tracing the history of iron further says, "One of the earliest examples of the use of iron for something more than pins and beads is the famous iron sword from tomb K at Alaca Huyuk. Clearly a ceremonial weapon, the blade seems to have been made of smelted iron. This tradition of early iron working was continued in the Old Assyrian period, the texts of which use two words, *amutum* and *asium* both identified as some sort of iron. It has now been suggested that *asium* represents iron ore, probably hematite, while *amutum* is the bloom iron smelted from the ore. *Amutum* is the metal, with objects always being described as made of *amutum*, never of *asium*. *Amutum* could also be refined (*sarapu*), presumably a reference to heating and forging in order to hammer out the slag".

Recent work on early iron objects from Palestine shows how this technology developed after 1200 BC. From Cyprus comes one of the earliest examples of quench-hardened steel, showing that by 1000 BC it was possible to produce a steel blade superior to anything that could be done with tin-bronze. One has to note the fact that quenching in cold water hardens only carburised iron or steel; it would have no effect on wrought iron.

As almost every country had local deposits of iron ore, the metal could be produced everywhere and at a cheaper cost than bronze. By the seventh century BC the Greek world was actually making use of an iron currency.

EARLY IRON IN CHINA

Needham suggests that in China wrought iron rather than cast iron may first have tentatively replaced stone, bone, and shell in common tools. As noted by Cheng T^a-K'un, iron rather than bronze terminated the Stone Age. As far as tools and implements were concerned, the Western Zhou culture was no better than that of a Neolithic survival with the exception of a few bronze *ch'ou* spades, *fu* axes and *pen* adzes. All the agricultural implements and working tools were made of stone, bone, or shell. Bronze was an expensive material, probably far beyond the reach of the common people. The Neolithic tools could be replaced only after a cheaper metal was produced. The answer was found with the introduction of iron. The metal was known in Western Zhou but it was not widely used until Chan-Kuo. Recent excavations have brought to light literally hundreds of iron artefacts from practically all provinces of Zhou China. As Needham attests, early in the history of the Chinese Iron Age, and well before the Han dynasty, cast iron necessarily rich in carbon became the dominant form of iron in China for all but the most highly stressed cutting or thrusting tools, such as axes and swords. By the early Han, a conventional baby blast furnace was in use for the production of such cast iron. The tradition of the bronze caster asserted itself sufficiently in the development of a cast iron, also high in silicon and phosphorus, that

in time the mould-boards of ploughs were cast of iron, along with stoves, kettles, bells, lamps, chisels, and so on. Even Chinese steel was made by the carburisation of a bar of wrought (low carbon) iron in a bath of cast (high carbon) iron.

About iron in China, Wagner (1993:406-7) says that the first iron was white cast iron, which is extremely difficult to cast. "The background of highly sophisticated bronze-casting techniques made it possible to cast agricultural implements of this material, but it is unlikely that acceptable ritual vessels and other symbolic objects could be cast in iron until much later. White cast iron also has inferior mechanical properties compared to bronze for weapons and indeed for most applications, but it would have been acceptable for agricultural implements because it was much cheaper. We do not know when wrought iron was first used in China: the earliest known well-dated wrought iron artefact in China is from the same period and place as the first cast iron artefact. While it is possible that the raw material for the early wrought iron artefacts was produced by direct smelting in bloomery furnaces, there is no evidence for this and it seems more likely that it was made by fining cast iron from blast furnaces. I suggest, though numerous blank spots in the archaeological material now available make the subject hazardous, a likely story for the chronology of early Chinese siderurgy: the initial invention occurred in the south-eastern state of Wu, in the fifth or sixth century BC; it spread from there to the southern state of Chu, perhaps in the early fourth century BC, where it was used for implements but not for weapons; from there it spread to the west and north, and by the beginning of the third century BC iron was in use throughout China for most practical implements and weapons. An important discovery, probably in the fourth or third century BC, was that cast-iron objects can be heat-treated to improve their mechanical properties; objects so treated are called in English malleable cast iron. In many ways they are almost as good as wrought iron or steel, and unlike objects of these materials they could be mass-produced. Very nearly all weapons were made of wrought iron, while very nearly all implements were made of cast iron. Mass production of cast-iron implements was extremely important for several centuries from the third century BC, and great fortunes were made by proto-industrialist ironmasters. In 117 BC iron production was made a monopoly of the Han state. The remains of several state ironworks of the Han period have been excavated, and these are clearly very highly centralized mass-production factories. It was not in north China that iron-smelting was invented, but in South-east China, in a culture with a very different relationship between rulers and populace and a bronze industry. We see here a pleasant example of an interplay between a high culture and a barbarian culture: the barbarians could not have developed the sophisticated bronze technology of the north, but in the specialized large-scale production units of the north it was much more difficult to arrive at the realization that a waste product could be useful. Further, this usefulness was much greater and more obvious in a society in which agricultural implements of bronze were common. The implicit "choice" of the blast furnace for the production of iron has special significance. A blast furnace is inherently an apparatus for large-scale production; it is hardly technically possible to produce less than perhaps a half-ton of iron per day, and efficiency increases dramatically as production increases. Efficiency also requires that the furnace be operated continuously over long periods: under pre-modern conditions, perhaps a week or a month at a time. Operation of blast furnace requires then a greater degree of reliability in all aspects of production, especially fuel and ore sources, the labour force, markets and transportation. At pre-modern production levels iron ore is seldom a problem; enough is available without deep mining in most parts of the world. Fuel, on the other hand, can be a very significant problem, and poor transportation conditions exacerbate a scarcity of fuel. These

are the requirements which led, in the 17th century Sweden, the American colonies, and third century BC China, to the organisation of iron production in iron plantations, in which a large isolated tract of forest was harvested for charcoal for the blast furnace. These were largely self-sufficient units, and long distance transportation was a significant factor only for their products, not for their inputs. I suggest that part of the reason for the establishment of the Han state monopoly of the iron industry was that these self-sufficient communities, isolated in mountain forests outside the reach of the state administration, constituted either a potential or an actual danger to the static agricultural society which was the ideal of Han political thinkers; especially since the iron plantations produced a commodity which had become a necessity for this same agricultural order" (Wagner 1993:406-8).

Discussing the earliest iron technology in China, Needham points out, "The fundamental feature of the development of siderurgy in East Asia, differing in this from all other culture areas, is that iron could be melted and cast there almost as soon as the metal was known. Elsewhere in the Old World nearly three millennia elapsed between the first iron-working and the first casting of iron, while the New World never knew the metal independently at all" (Needham 1980: 507-42).

Needham however states that in China metallic iron, first meteoritic, then smelted, seems to have been known and used from about the 12th century BC onward, though systematic iron technology started only from about the seventh century BC. If the first products of smelting were blooms of carbon-free iron, as in the western part of the Old World, they have left hardly any traces, archaeological or textual.

Cast iron appears from the fourth century BC onward at the latest, used both for agricultural implements, moulds for tools and implements, and weapons of war. The factors connected with this early appearance of the fully liquid metal, some 17th centuries before it could be obtained at will in the West, probably include the following: the use of ores exceptionally rich in phosphorus or the addition of phosphorus rich minerals to the blast furnace charge; the availability of good refractory clays, which allowed adequate though small blast furnaces to be built as well as crucibles in some parts of the country; the application of reciprocating motion to double-cylinder piston-bellows for metallurgical work as early as the fourth century BC; the invention, probably in the second century BC of the double acting single cylinder piston-bellows, which allowed a continuous blast; iron tuyeres were provided at least as soon as the beginning of the third century AD; the application of water power to these bellows and perhaps even to larger hinged types in the first century AD and perhaps long before, which permitted the building of a very hot pile around crucibles, the contents of which were protected from sulphur by luting. The consequent abundance of cast iron in ancient and medieval China constituted a radical difference from the siderurgical industry in the rest of the Old World (Needham 1980).

If steel was produced by cementation of wrought iron in the Zhou and Chhin periods, there is little or no trace of it, archaeological or textual. The characteristic Chinese process of steel making was decarburisation direct from cast iron, known for centuries as the "hundred refinings". It depended on the direct employment of an oxidising blast of cold air. Developing alongside the more drastic process of fining cast iron to wrought iron, it was fully in use, it seems, from the second century BC onward. By the 17th century AD the oxidising technique had led in China and Japan to procedures whereby something like cast steel was produced. Direct migration of Chinese workmen skilled in the technique immediately preceded the inventions associated with the name of Bessemer.

Needham thinks that the welding of hard and soft steels for weapon blades was practised in China at least as early as the third century AD, and in the seventh century the art was transmitted to the Japanese. Since the process was also practised among some Western European peoples from the first to the ninth centuries, the original focus may have been in Central Asia, whence it would have spread both east and west from about the second century. The damascene pattern in the Chinese culture area derived not from welding processes only, but also, though less extensively, from the importation of hypereutectoid wootz steel from India by about the sixth century AD. Once cast iron became available in Europe from about AD 1380 onward, all these ways of using it appear within about two centuries. If they and the blast furnaces had been, as has usually been supposed, independent inventions, one would perhaps have expected a slower evolution (Needham 1980).

It was far back in late Shang Dynasty that iron meteorites were used to be forged into blades, and cast with bronze into weapons. This process was passed down all along to the end of Western Zhou, perhaps providing impetus to the origin of certain iron-smelting technologies.

Archaeological excavations have shown that artificial iron-making may have begun in the late Western Zhou in China. It is worth noting that the smelting and casting of pig iron began only about two hundred years later, *i.e.* the late Spring and Autumn periods. Only another one hundred years had passed before pig iron was in wide use for casting production tools, especially for farming implements, thus marking the beginning of the Iron Age in China.

Correspondingly, a series of outstanding inventions related to pig iron came springing up one after another. Two of the most important were the iron mould casting and cast-iron toughening techniques. In these, pig iron castings were changed into white-heart malleable cast iron or black heart malleable iron through decarbonizing heat treatment or graphitizing heat treatment respectively. Others were the later ones of puddling iron (Western Han 206 BC-AD 8) and Guan-steel (made by smelting pig iron and puddling iron together, about the end of Eastern Han AD 25-220). These revealed a technological course of development, which, though markedly different from that in ancient Europe, led to the same goal. This unique instance in the history of technology is interesting and thought provoking. Wagner says, "It was here that the blast furnace for smelting iron was developed on the basis of large-scale copper-smelting furnaces... Iron had probably long been familiar to the furnace operators as an unintentional waste product, a sign of improper furnace operation; the invention of iron was essentially the realisation that this waste product could be made into useful artefacts" (Wagner 1993:405-406).

EARLY IRON IN JAPAN

Imamura gives the following list of iron objects from early Japan. Belonging to the Yayoi period are swords, halberds, arrow-heads, axes, chisels, point planes, knives, spade-shoes, reaping knives, sickles and fish-hooks. The oldest specimen is a flat axe discovered in an Initial Yayoi pit dwelling at Magarita. It is made of high-grade forged steel. The socketed iron axe from the Early Yayoi Saitoyama site is a cast iron product. Judging from the quality and casting technology, these were most certainly imported from China. Although not all domestic products are distinguishable from imported Korean and Chinese ones, the appearance of unique Japanese forms in the first half of the Middle Yayoi phase provides the clearest evidence for the beginning of the domestic manufacture of iron tools. Such Japanese forms became prevalent in the Late Yayoi period. Imamura explains the extinction of stone tools throughout Japan in the Late Yayoi (except for northern Tohoku and Hokkaido) by the diffusion of iron. Such iron tools were most probably

made of imported iron material. A section concerning "Bian Chen" in Wei-shu written in the third century AD, reports that iron resources are found in southern Korea and that the "Han", "Ye", and "Wa", namely Japanese, actively procured it. It also mentions that they used iron as a medium of exchange, like money in China. However, as of now there is no positive discovery of Yayoi iron smelting sites that would provide evidence of the domestic production of raw iron. (For Japanese chronology see Table 10.4.)

Sasaki says that the earliest direct evidence of the use of iron comes from the Imagawa and the Magarita sites both in Fukuoka prefecture. The former, dated to the Yusu phase of the Final Jomon Period (the fifth to fourth century BC), has yielded an iron arrow-head, and the latter of the even earlier Yamanotera phase (the tenth to sixth century BC), has yielded an iron axe. The indirect evidence comes from the Final Jomon Yusu phase at the Itatsuke rice paddy site where stakes separating rice paddies and a path between them were sharpened by a blade, presumably of iron. Other discoveries of the use of iron have been made in Kyushu, the coast of the Inland Sea, and Kinki regions and date to the Final Jomon Period and phase I Yayoi Period. Most of the artefacts are tools for wood working, such as an axe, a knife, and a plane. Iron, at that time, however, was not manufactured in Japan and did not play a major role in technology; it was stone tools that were still predominant. Sasaki points out, "An interesting point concerning the early use of iron in Japan is that almost all of the iron artefacts dated to this time period are of wrought iron, and they predate Han Dynasty's founding of four colonies in the northern Korea in 108 BC which helped spread the use of cast iron in Korea. Kawagoe points out the possibility that the early knowledge of iron in Japan came from the southern part of China (Jiannan), where the Chu civilisation (403-221 BC) developed tradition of using wrought iron during the Warring States period, and where methods of rice cultivation are believed to have originated.

Sometime after Japan began to import iron tools, iron production began. Hashiguchi states that some of unidentifiable iron objects discovered in the terminal phase I and early phase II of the Yayoi Period (the second century BC) at the Ayaragi site in Yamaguchi prefecture may be iron raw material extracted from iron ore. Shiomi (1986: 239) tends to support this view by pointing out that the morphology of Japanese iron knife and plane is very different from the Korean and Chinese counterpart, and that they may have been manufactured in Japan.

Sasaki informs us that the other iron artefacts, which are believed to be unique to Japan, include an iron halberd and a socketed iron axe whose socket is round in cross-section. The earliest evidence of the former comes from the phase III at the Suku site, and the latter from the phase II at the Yoshigaura site in Dazaifu city, Fukuoka prefecture. Shiomi believes that by that time iron production had started in Kyushu. Direct evidence of iron production has been discovered at the Akaide site, Kasuga city, Fukuoka prefecture. Structure No. 33 and Pit No. 5 are attributed to an iron workshop, and archaeologists have discovered iron raw materials, unfinished products, iron arrow-heads, as well as burnt walls. A complete sequence of producing a socketed iron axe has also been reconstructed.

Sasaki says that most of iron objects dated to phases II through IV are tools for wood working. In addition to tools, iron weapons became common during the phase III, replacing the bronze "weapons" which had already been transformed into ritual paraphernalia. The Tateiwa site, a phase III burial, where only one bronze spear (medium-slender type) was discovered, yielded four iron swords, one iron spear, two iron halberds, and some iron planes and knives.

Until the first century AD, Sasaki informs us that almost all agricultural tools were of wood

or stone, but they were all replaced by iron counterparts during phase V (the second and early third centuries AD). These include the iron sickle, plough-head, and lunar-shaped object for harvesting. Most of the iron artefacts of this time come from Kyushu. In rest of the western Japan, all the stone tools for these functions completely disappeared by the end of phase V, suggesting that iron tools replaced them, although we do not have much direct evidence (Sasaki in press) (see also chapter 10).

IRON IN INDIA

With this global perspective of the development of iron technology, let us turn to India and begin with the earliest literary evidence.

Literary Evidence

Kosambi has quoted the earliest literary reference to iron in India, "For the Iron-ore country, however, we have one ancient record well worth consideration, the Pali *Sutta-nipata*. The language is the most archaic of any work in the whole Buddhist canon; the style too is simple and direct. Asoka mentions several of the *suttas* now found in this book (and nowhere else in the canon) with special approval in an edict addressed to the Buddhist Order. There is no question but that the work is pre-Asokan and contains the oldest of Buddhist tradition. The fourth discourse in the collection is of 'Farmer Bharadvaja', (*Kasi-Bharadvaja-sutta*), a brahmin who farmed land at Dakkhinagiri in Magadha. This is the portion of Mirzapore district along the southern bank of the Ganges. The word *phala* for ploughshare occurs in both the prose and the metrical portions of the discourse. The simile runs: 'like a *phala* heated for a whole day and plunged suddenly into water....' Bronze treated like this would become brittle and useless, apart from being much too costly for ploughshares. Iron reduced from ores by any primitive method comes out as a spongy mass, which has to be heated and forged repeatedly as well as hardened by sudden chilling before it is of any use for tools. The death of the Buddha is dated at either 543 BC or 483 BC. The sermon is undated, but its context shows that the Buddha had not reached the height of his reputation in Magadha, being then comparatively unknown. It follows, even on the latest possible dating for the Buddha's decease, that agriculture and the iron ploughshare were in general use in Bihar before 500 BC. The particular region of the *sutta* still has good supplies of an important and rich iron ore, haematite.... Remembering that food gathering was so easy that less metal was needed, the date 800-700 BC, therefore, seems to me a reasonable beginning for the iron age in India, meaning thereby specifically the Gangetic basin where iron was most needed and most likely to have been worked" (Kosambi 1963: 318).

The other old references to iron are in the *Ayurveda*.

Iron in Ayurveda

Jha *et al.* (1989) have mentioned the following:

1. Ayurvedic medicinal system was very much developed in 8th c. AD and according to Sushruta, iron and steel were known even as early as 700 BC.
2. The Ayurvedic physicians were very selective in the choice of metallic source used for the production of iron *bhasma* (oxide or other compounds) such as use of biotite instead of haematite or other minerals of iron.

3. By experience they had arrived at the conditions for optimum extraction of iron from biotite and convert it into *bhasma* (oxide) for medicinal use.
4. The experiments also indicate the possibility of production of steel as shown in Fig.10 (in Jha *et al.* 1989) which has been mentioned to be used for making surgical instrument used by Sushruta in 700 BC (Jha *et al.* 1989).

In recent years the most detailed study of early iron has been carried out by Chakrabarti in his *Iron Age Studies in India—A Historical Outline* (Chakrabarti 1992). Below we will trace the history of research on iron as described by Chakrabarti (all references in this section can be found in Chakrabarti 1992).

The history of research on Indian pre-industrial iron goes back to the 18th century. Chakrabarti describes its phases.

History of Iron Studies

This phase (c. AD 1795-1850) was marked by a scientific interest in understanding the properties and the manufacturing process of pre-industrial Indian steel which came to be known in Europe as wootz. This word was derived from the Canarese term *ukku* meaning steel (Yule and Burnell, 1903: 972-73). That pre-industrial Indian steel had a reputation in contemporary Europe is exemplified by its sale in Hamburg in 18th century as Indian steel and also as referred to by Remour in 1722 in his memoirs.

The first significant publication on the subject was by George Pearson in 1795. Pearson's paper, "Experiments and Observations to Investigate the Nature of a kind of steel, Manufactured at Bombay and there called Wootz: with Remarks on the Properties and Composition of the Different States of Iron" (Pearson 1795: 322-46) is another landmark on the study of iron in India.

Chakrabarti enumerates several reports on iron-smelting practised by the Kol tribe of eastern India and other such references: Oldham 1930; Rose 1931; Cracroft, 1832; Heath, 1832, 39; Jacob, 1843; Lt. Yule, 1842; Marcadieu, 1955; Shastree, 1844; Hannay, 1857; Abbott, 1848; Piddington, 1955; Jackson, 1845; Torrens, 1851; Baker, 1854; T.H. Newbold, 1846. These writings described the extent, distribution and methods of pre-industrial iron-smelting in India.

Incidentally, Chakrabarti records the statement of a letter from J. Stodart who found that the wootz or steel of India was decidedly the best he had met with and that it promised to be of importance to the manufacturers of Britain.

However, on the problems of antiquity and origin, J.M. Heath seems to have been the only writer of this period who had an interest and an opinion: "The antiquity of the Indian process is no less astonishing than its ingenuity.... One can hardly doubt that the tools with which the Egyptians covered their obelisks and temples of porphyry and syenite with hieroglyphs were made of Indian steel". In this context Heath referred to the classical writers, who mentioned an Indian present of steel to Alexander.

During the next phase, Chakrabarti defines six interrelated lines of research. The earlier metallurgical interest continued. John Percy classified the pre-industrial Indian smelting furnaces into three basic types (Percy, 1864: 254-70). In 1908 Turner published *Metallurgy of Iron* which was a concise summary of the distribution of ores and the pre-industrial smelting practices. In 1881, Valentine Ball in Part III of *A Manual of the Geology of India* consolidated the geological evidence (Ball, 1881: 335-414). In 1880, Ball published *Journals of an Indian Geologist* (Ball,

1880) which contained an account of the iron-smelting practices of the tribal group of the Agarias in the Chhotanagpur plateau. In 1899, S.A. Bilgami (Bilgami, 1899) wrote on the iron industry in the territory of the Nizam of Hyderabad. According to Watt, to him belongs the credit of having been the first to show that iron can be successfully smelted in India on European principles (Watt, 1890: 504-5).

A synoptic account of the east Indian iron industry as a whole with considerable emphasis on the pre-industrial practice was given by Charles Ritter Von Schwarz in 1901 (Schwarz, 1901). An interest in the composition of early Indian iron objects was an important feature of this research-phase (Hadfield, 1912). There was an increasing speculation on the origin and antiquity of iron (Lester, 1912:4; Roscoe and Schorlemmer, 1897: 935; Percy, 1886: 19; Sahlins, 1913:56). Swank thought that India was acquainted with the manufacture of steel from a very early period (Swank, 1890: 8).

There was an emphasis on the literary data too. This is evident in a number of writings (Foote, 1901: Preface). *Ferrum Indicum* appears in the list of articles subject to duty at Alexandria (cf. Ray, 1902). Schoff outlined the mode and quantity of the transport of steel from India to the Roman world. Finally, there was an attempt to systematise the whole range of evidence (Neogi, 1914).

In the third phase, basing exclusively on the archaeological data, D.H. Gordon (1950) thought that iron could have been introduced in India between 600 and 700 BC, which possibly made R.E.M. Wheeler write some time later that iron came to India only with the Achaemenids.

Gordon's paper was the first one to discuss the beginning of Indian iron solely on the basis of the archaeological data and thus marked a distinct break. Chakrabarti complains that Gordon's work as also of subsequent authors give no indication of the fact that iron was of common interest to commercial, metallurgical and geological studies.

The ^{14}C date of around 1000 BC for the discovery of iron in the Painted Grey Ware levels in the upper Gangetic valley at Hastinapur militated against the assumptions of Gordon and Wheeler. D.D. Kosambi in 1963, as we noticed above, on the basis of literary evidence, put the date of the beginning of iron in the Gangetic valley at 700-800 BC (Kosambi, 1963).

Chakrabarti rightly claims that the final and current phase (1976 onwards) began with his definitive study of the problem in 1976. In this study Chakrabarti identified six early iron-using centres in the subcontinent: Baluchistan; the Northwest; the Indo-Gangetic divide and the upper Gangetic valley; eastern India; Malwa and Berar in central India; and the megalithic south India. This scheme only slightly differs from Tripathi as discussed below. In this study Chakrabarti had concluded that: (1) the iron in central and south India is, on the present showing, earlier than the iron in the north-western periphery of India. The central Indian centre seems to be the earliest of the six early Indian centres. (2) Iron seems to have entered the Indian productive system by c. 800 BC. The literary data alone seem to suggest c. 700 BC. (3) A look at the list of iron ore areas will show that all these early centres are either in or near the ore areas. The evidence of pre-industrial smelting also comes from almost all these areas. (4) The evidence of pre-industrial smelting and rich ore deposits is very impressive in central and southern India which also seem to show the first evidence of Indian iron. (5) The first Indian iron tool-types do not significantly correspond to the iron tool-types known in West Asia. There is no other demonstrable proof of diffusion during that period from West Asia to the peninsular block of India. (6) There is an apparent continuity between the early and the contemporary (pre-industrial) traditions of iron metallurgy in India. These points suggest to him that India, was a separate and possibly

independent centre of manufacture of early iron (Chakrabarti, 1976).

In his 1992 book Chakrabarti however changes his views and concludes that there are at least two regions in which the beginning of iron may be put in the second half of the second millennium BC. Chakrabarti claims that the occurrence of iron at Ahar in Rajasthan and in the post-Chalcolithic black-and-red ware phases of Nagda, Eran, Dangwada and Prakash in Malwa decidedly goes beyond 1000 BC, perhaps to the middle of the second millennium. He thinks that the issue is clinched by the discovery of iron at Lothal.

In Karnataka, in south India, the early radiocarbon dates of the level of Neolithic-megalithic transition at Hallur are now supported by the thermoluminescent dates from the relevant context of a neighbouring site. This is an important development and clearly strengthens the case of a pre-1000 BC beginning of iron in south India. Both in the upper Gangetic valley and eastern India the use of iron began unmistakably around 1000 BC (Chakrabarti 1992).

I would say that pushing back the beginning of iron to mid-II millennium BC is really not warranted by evidence. The excavator of Ahar placed the layers under Chalcolithic phases. Accidental smelting of iron from copper pyrites is very ancient indeed, as has been pointed out by Muhly for Anatolia (see above). In fact, some TL dates for south Indian megalithic sites seem to go beyond 1400 BC. But the TL dates have large errors and uncertainties. Nowhere in the world iron use on a regular basis has begun before 1200 BC. Claiming it for India alone will be a bit anomalous. Even Chakrabarti agrees that the literary data suggest that by the time of the *Satapatha Brahmana* (c.800/700 BC) iron was a common metal to be associated with the ordinary people.

Moorey (1994: 279) explains that "It is possible under certain conditions to produce iron when smelting copper; it is increasingly thought likely that a significant proportion of the iron current in the Near East, at least before the Late Bronze Age, might have been produced in the process of smelting copper, or possibly lead. As Wertime (in Wertime and Muhly [eds.] 1980: 16) pointed out 'The earliest smelting must not be seen as a conscious selection of a pure ore but as the experimental employment of an ore mix which could alternatively yield lead, copper, or iron, or a mixture of all three'. If iron oxide in any one of its three forms (haematite; limonite; magnetite) was accidentally or deliberately added to the furnace charge as a fluxing agent, in smelting copper or lead, the iron would combine with the silica in the ore to form slag that would melt and eventually run off. In circumstances of high temperature and extreme reducing atmosphere, small bits of relatively pure iron would have been produced (cf. Cooke and Aschenbrenner 1975; Gale *et al.* 1990)".

This information may be relevant for the Indian scholars who claim the presence of iron from Chalcolithic and even Harappan levels to mark the advent of iron technology.

Chakrabarti is categorical that the archaeological picture clearly suggests India to be an independent and early centre of iron technology, and this cannot be explained by any diffusionary postulate.

Iron furnaces in the South

Chakrabarti refers to the megalithic site of Kodumnal in the Periyar district of Tamil Nadu. The megalithic level here has been dated to c. 250 BC. "A large oval-shaped furnace surrounded by a number of small furnaces was exposed in the bottommost level. Vitified crucibles collected here which appear to be *in situ* may suggest that the large furnace was used to stack up a number of crucibles containing iron and carbon to produce steel by prolonged heating".

Another detailed study is from Vidarbha, Naikund (lat. 21°2'N; long. 79°10'E), a megalithic habitation and burial site located about 42 km north-north east of Nagpur in the Vidarbha region of Maharashtra. The site is reported to have 73 stone circles, a majority of them undisturbed, with two habitational mounds, all surrounded by megalithic circles and situated on the left bank of the river Pench (Deo and Jamkhedkar 1982).

About 200 m eastwards of mound II and 130 m south of mound I were located the remains of a smelting workshop designated as mound III. This mound was located with the help of a Resistivity Recording Metre. At a depth of 1.25 m was exposed an iron smelting furnace. The furnace was built of circular clay bricks of a thickness of 4 cm. The diameter of the furnace was about 30 cm and height about 25 cm. The bottom of the furnace was paved with bricks and was fused with slag and cinders. There were holes to pass air into the furnace from the bellows. Besides these, a large quantity of iron slag was found. According to Gogte's observation, the Naikund Megalith folk used about 10 to 12 kg iron ore for a single smelting operation producing 3.0 to 4.2 kg of pure iron. It has been stated that Naikund is the first megalithic site to have given evidence of an iron smelting furnace (Gogte 1982: 52-59).

The habitational deposits and burials were rich in iron artefacts at Naikund. The artefacts were composed of a wide range of dishes, ladles or lamps, daggers, knife blades, adzes, hoes, axes, chisels, clangs and hooks. The iron found was of a very pure quality, devoid of any other intrusions except carbon, which qualified it to be designated as steel. The local iron ore was utilised by them.

WOOTZ IRON

While discussing Chakrabarti's history of iron studies in India above, we briefly discussed the problem of wootz. Lowe (1990: 237) has carried some recent studies on wootz which we will describe briefly below.

"In the crucible controlled chemical and physical processes during the melting of an iron charge, an ingot was produced which was essentially a white cast iron of high carbon content. The ingot was transformed by heat treatment and during the forging process into steel that was particularly suitable for sharply edged tools. The crucible was not only sufficiently refractory to withstand long-term firing, but also had insulating properties which slowed the cooling rate of the molten metal at the end of the firing, thereby producing the distinctive crystal structure of the so-called wootz steel.... The brittle structure of the crucible, which could be broken after firing, enabled retrieval of the ingot. The observed thermomechanical properties of this refractory thus were well adapted to the manufacturing process" (Lowe 1990: 237). Andhra Pradesh and Tamil Nadu were the world famous centres for the ancient wootz steel production. Low also agrees that 'Wootz' is derived from the Kannada word *wooku* (ukku) which means steel. The Indian iron masters had realised the effect of addition of carbon to iron and the excellent cutting edges formed on carbon steels. Low says that Wootz steel was exported to Europe even as early as 400 BC. The trade was carried through Damascus where this steel was used for the manufacture of swords and hence it was also known as Damascus steel. Prakash (undated) says that steel was manufactured by two techniques: i) By carburisation of wrought iron rods and melting in small crucibles; and ii) by decarburisation of white cast iron.

Prakash thinks that the generation of high temperature ($>1600^{\circ}\text{C}$) was not a constraint and the foot operated bellows were sufficient to provide air for the combustion of charcoal. He thinks that wrought iron having very low carbon could be converted into carbon steel of desired

composition by the 'wootz' process and the application of processes of forge welding, hardening, tempering and probably carburising were well developed by the end of AD 300.

SPATIAL DISTRIBUTION OF IRON TECHNOLOGY IN INDIA

We briefly discussed Chakrabarti's views about different iron using zones in South Asia. Now we discuss a more recent scheme proposed by Prakash & Tripathi (1986: 568-79). They have identified the following geographical zones of the distribution of early iron technology in India.

Zone A — Northwestern India

Pirak, a site in the Kacchi plains of Baluchistan, has also yielded iron in its mid-phase, which is dated 800 BC. In the Swat valley, the Gandhara Grave Culture, known primarily for its burials, also bears iron. Period III, a phenomenon of the Iron Age, is closely associated with a grey coloured pottery unlike any grey ware of other Indian sites, roughly dated 900-800 BC.

Gufkral, a site in the Kashmir valley, has yielded iron in the megalithic context. The dates are said to be early but details of the excavations are not yet available.

Zone B — Painted Grey Ware (PGW) Culture of North India

Several PGW settlements have demonstrated a trend towards growth in size and technological expertise with the appearance of glass and iron, though bits of iron have also been associated with the culture immediately preceding it (see Fig. 11.1).

Zone C — Black and Red Ware (BRW) Culture of Northeast India

At most of these sites BRW continues from the chalcolithic cultures to the Iron Age but with many new features.

Zone D — Megalithic Culture of Central India

Iron appears in the megalithic burials of the Vidarbha region in central India with black and red (B&R) ware. This B & R ware is quite different from that found in the Northeast. Excavations have been conducted at several sites in Maharashtra *e.g.*, Takalghat-Khapa, Mahurjhari and Naikund. The iron objects of these sites appear more sophisticated, and are more warlike. We have already described above the biggest find in this region of the furnace at Naikund, complete with tuyeres and slag.

Zone E — Megalithic Culture of Peninsular India

Megalithic sites are found in Mysore, Kerala, Madras, Andhra Pradesh and several other places in peninsular India. Most of these burial sites, like Brahmagiri, Sangankallu and Maski were excavated in the early fifties and were then dated to fourth-third century BC. Subsequent excavations in the same regions at Hallur, Tadakanhali and Paiyampali have necessitated review of the earlier theories on iron in this cultural zone. The common pottery is black and red ware of the post-neolithic phase. The sites of this zone have recently been TL dated to around 1000 BC and older.

Prakash & Tripathi state that culturally each of these zones has distinctive and divergent features and few common traits, except for Zones B and C which have comparable pottery. They think that this general dissimilarity indicates that iron technology developed independently in

several of these centres.

They suggest that the fact that iron was in full use in the entire subcontinent by 1000-900 BC also supports the theory of independent and indigenous development of iron technology. They think that its diffusion over such a vast area in this short period does not seem feasible. Diversities in the cultural material of the above zones also strongly support this divergent development.

According to Prakash & Tripathi (1986) from the archaeological and ethnotechnological evidence, it is evident that iron first appeared in India between 1300 and 1200 BC and by 1000 BC was in use all over the subcontinent (I however think that the case for such antiquity has yet to be established). They point out that tool typology indicates that in the first phase iron was used only for hunting and cutting tools and that at a much later stage it contributed to economic and cultural growth through agricultural, constructional and domestic applications.

The earlier objects were purely wrought iron but, gradually, iron craftsmen and smiths mastered iron making technology, forging and shaping and forge-welding techniques. They also developed unique techniques of purification of iron and production of crucible steel, which became known worldwide as wootz, and later as Damascus steel (Prakash & Tripathi 1986: 568-79).

They explain that their study of material and heat balances indicates that ancient craftsmen could attain sufficiently high temperatures to smelt iron with the traditional foot-operated bellows. Craftsmen probably also knew that maintenance of furnace temperature higher than 1200°C would lead to the melting of iron and production of cast iron instead of wrought iron. The consistency of chemical composition is an added proof of the technological skill of the ancient iron smelters. By AD 300, India had definitely mastered production, forging, welding and probably heat treatment of wrought iron as well as steel as seen in excellent examples like the Delhi Iron Pillar (Prakash & Tripathi 1986: 568-79).

ETHNOARCHAEOLOGY AND IRON

Tripathi and Mishra (1977: 59-68) have carried very interesting ethnoarchaeological studies which have a great relevance to understand the ancient iron technology. We will therefore discuss it in some detail. The following account is mainly based on their work.

Tripathi and Mishra claim that almost every possible locality has at least a minor iron-bearing deposit. It is also available in several rivers (flowing from Himachal Pradesh) in the form of magnetitic sand. Metallurgists like Tylecote have argued that the early workers preferred low-grade ores for technical reasons. Most of the pre-industrial iron workers reside in close proximity to the mineral deposits. They cover about 15-20 km during one trip and collect approximately 45-60 kg of ores necessary for 3-4 days of smelting. This is basically a group activity involving several families. Even today, in such areas where pre-industrial iron-working continues, not much mining is involved.

Tripathi and Mishra inform us that iron produced by these traditional smelters is preferred by the local people to factory-produced iron because of its high durability, ductility and capacity to provide a better cutting edge. They mention the following special features of pre-industrial metallurgy:

1. The size of the furnace is very small, barring a few exceptions. The height of the furnace varies between 0.6 and 1.2 m. The diameter at the base: 0.25 m 0.5 m.
2. Charcoal is the fuel used. The Madhya Pradesh Chhattisgarh tribes use sal or teak wood to produce charcoal. This is a purer fuel with a lower sulphur and phosphorous content.

The metal thus produced is naturally low in sulphur. Phosphorous is the only element which remains in metal produced from ores which contain this naturally.

3. Generally no flux is used, even when lime - which removes sulphur from the products—is easily available.

4. The smelting may be considered wasteful and low yielding as only 4-5 kg of iron are produced after utilising about 15-20 kg of ore.

5. The high percentage of charcoal used in traditional working has several advantages. When the charcoal proportion is high, the iron will contain more carbon bringing this metal into the category of steely iron, which is superior to wrought iron, the latter being brittle. Prolonged contact with charcoal in this process carburises or hardens iron, making it malleable and providing the object with a sharper and longer lasting working edge. They report that the Chhatisgarh smelters use about 30-40 kg of charcoal for 15-20 kg ore, i.e more than double the amount. Hughes (1873) reporting on the iron smelting of the central Provinces stated that for the production of 1 kg of bloom 3.6 kg of ore and 4.97 kg of charcoal were consumed. The bloom was then refined twice, losing about 54-60% of its weight, drawing on more charcoal (up to 1.72 times the weight of the bloom).

6. The temperature in the furnace is not uniform. It is around 600°C in the upper portion, going up to 1300°-1400° C or sometimes nearly as high as 1500°C near the tuyere. A close study of the whole production process and temperature mechanism has led metallurgists to the conclusion that '... the traditional smelter is constrained by the low temperature in the furnace and the process is finely tuned to his requirements, any rise in the slag melting temperature can ruin the product'

7. The tribal smelters are almost 'religiously' particular about the type of wood they use to make charcoal for fuel, the clay, the time and spot chosen for smelting (as external humidity supposedly affects their working), and the ores that they use. Because of its purity and other advantages, magnetite bearing sand from rivers is used by several such groups. They do not want to take the risk of experimenting.

8. The smelters were capable of producing a variety of iron similar to the famous 'Damascus' or wootz steel of south India. Ingots of this steel have been analysed. It is a high quality steely iron with a homogeneous structure. It is at times referred to as crucible steel, which also explains the technique of its manufacture. Objects forged out of this steel found their way to different parts of the world in the early centuries of the Christian era. It was only much later that it was known to be of Indian origin. During their investigations they came across a white iron or *chakra loha* which was produced using magnetitic sand in Sarguja district, Madhya Pradesh. The Mahuli Agarias are adept in this art and the product is used for making weapons. Today even gun-barrels are clandestinely made from this iron or steel because of its superior quality.

9. Tripathi and Mishra (1977: 59-68) emphasise that the pre-industrial iron working technology tallies closely with the archaeological evidence. Ethnographic data fill in the lacunae in our understanding the ancient Indian iron metallurgy, and amply demonstrate the characteristics of early iron technology using the bloomery process of smelting in small-sized furnaces. According to them, the small pits (20-25 cm), filled with ash, charcoal and bits of slag occasionally found in association with finished iron objects from Painted Grey Ware, Black-and-Red Ware or Megalithic cultures probably represent the remains of ancient smelting/forging activity. Some efforts have been made to reconstruct these iron working processes by Gogte (1982) in the case of Naikund

and Hegde (1973, 1991) for Dhatwa.

More recently a similar attempt has been made by Tripathi (1995; Tripathi and Tripathi 1997) for Khairadih, district Ballia, Uttar Pradesh. This site belongs to the late NBPW (Northern Black Polished Ware) period. All these examples have a common feature of using small-sized bloomery furnaces capable of producing wrought iron.

Tripathi and Mishra think that the fact that not all iron objects of the sixth-fourth centuries BC were carburised does not indicate a lack of knowledge of metallurgical processes. Perhaps the smiths exercised a deliberate and conscious choice and manufactured only what was required. This assumption is supported by the texts from the sixth century BC onwards. The Pali texts of the fifth-fourth centuries BC make a clear reference to quenching especially for ploughshares which had to be sharp edged, durable and malleable (mentioned above). The variety of iron samples - *kant loha*, *tikshna loha*, *munda loha*, being soft iron, carbon-steel and cast iron respectively, have also been mentioned. The detailed and intricate process of manufacturing such divergent types of iron have been elaborately described in the early medieval alchemy texts like the *Ras Ratna Samuchchaya*.

They do not think that the growth of technology was a unilinear process that simple techniques gradually led to more complex ones. On the basis of literary and ethnoarchaeological data they suggest that different techniques were learnt and applied simultaneously as required by the tool to be fabricated. For example, the techniques necessary for the manufacture of sharp edged weapons or longer lasting, sharp edged craftsmen's implements did not have to be the same as those for household items, utensils, etc. The analyses of objects from excavations indicate the prevalence of several techniques within a cultural period. This is often interpreted as due to lack of sufficient skill to ensure uniformity and standardization. They however think that ethnographic evidence proves that these ancient workers make a deliberate choice of ore, technique and product. This is evident from the examples of the Asur-Birjia of the Netarhat plateau, the Mahuli Agarias (producing white iron) or the Parsa group of Agarias and the Kamis of Darjeeling (manufacturing iron specifically for weapons like swords and now for gun barrels). Such settlements are examples of the *kammar-gama* (artisans' settlements) mentioned in Pali literature and the *Arthashastra* of Kautilya.

As mentioned by Wagner, quoted above, self-sufficient iron making communities played a significant role during the Han dynasty in China for iron production. There seems to be some similarity with these Indian communities of iron smiths.

Tripathi and Mishra conclude that the quality of iron is closely inter-linked with the demand and larger production. Unless full-time workers took up the task of manufacturing good quality iron, the demand for low grade inferior metal naturally remained restricted. Metallurgy had to attain a certain standard to be able to produce steely iron in large quantities. Only such iron was capable of fashioning quality tools and implements useful for crafts and agriculture.

The fact that there are a large number of iron smelters still surviving despite the most adverse conditions suggests to them: (a) that there was an old tradition of such crafts; (b) that these artisans were full-time iron workers; (c) that they have been able to make a livelihood out of this craft, and (d) that the quality of their product is still in demand even when compared with more cheaply available factory-made iron. This is the strength of traditional iron working.

We have discussed the role of the central Himalayas in north Indian iron technology in chapter 8 and in Agrawal & Kharakwal (1998).

Before we conclude this chapter, we may note that in the Ganga valley the urbanisation

ushered in only by the mid-I Millennium BC when iron technology was well established as an industry. Though the Ganga valley had the beginnings of agriculture going back to 8000 BP and of copper going back to II Millennium BC, the advent of urbanisation had to wait till iron technology became well established.

Table 11.2 Calibrated ages of Raja-Nal-Ka-Tilla (U.P.)

(1)	PRL-2045 (Layer-10) 3260 ± 90 BP
	1SIGMA: 1622 CAL BC...1426 CAL BC
	2SIGMA: 1742 CAL BC...1378 CAL BC
	1348 CAL BC...1316 CAL BC
(2)	PRL-2046 (Layer-9) 3100 ± 90 BP
	1SIGMA: 1500 CAL BC...1490 CAL BC
	1448 CAL BC...1256 CAL BC
	1240 CAL BC...1214 CAL BC
	2SIGMA: 1524 CAL BC...1112 CAL BC
	1098 CAL BC...1056 CAL BC
(3)	PRL-2047 (Layer-6) 2890 ± 80 BP
	1SIGMA: 1196 CAL BC...1188 CAL BC
	1164 CAL BC...1143 CAL BC
	1132 CAL BC... 976 CAL BC
	970 CAL BC... 930 CAL BC
	2SIGMA: 1304 CAL BC...1284 CAL BC
	1268 CAL BC... 894 CAL BC
	882 CAL BC... 846 CAL BC
(4)	PRL-2047 (Layer-7) 3050 ± 90 BP
	1SIGMA: 1406 CAL BC...1198 CAL BC
	1186 CAL BC...1164 CAL BC
	1143 CAL BC...1132 CAL BC
	2SIGMA: 1508 CAL BC...1482 CAL BC
	1456 CAL BC...1024 CAL BC

SUMMARY

It seems that the emphasis of the scholars working on the early Iron Age in India is directed more towards proving the unique antiquity of iron metallurgy in the world and its independent origins. The technological studies of the transitional states from copper to iron are yet to be delineated. Nor do we know when actually iron supplants both bronze and copper. With iron smelting known from Anatolia even before the III Millennium BC, and the possibility of accidental production of iron during smelting of pyrite ores for copper, mere presence of iron does not tell us much archaeologically or technologically. Table 11.2 calibrated AMS dates show that iron at Raja-Nal-ka-Tila go back to 12th century BC. But what do they tell us? Clearly the need is to look for a polymetallic stage, transitional stages from copper to iron and the processes of socio-economic impact of iron in the I Millennium BC.

The next chapter will address itself to the history of brass and zinc.

CHAPTER 12

ZINC AND BRASS

CONTENTS

- HISTORY OF BRASS AND ZINC
- ZINC IN CHINA
- ZINC IN INDIA
- SUMMARY

HISTORY OF BRASS AND ZINC

Quite often there is confusion about the early occurrences of brass, zinc and zinc extraction by distillation process. Though brass has been reported from China from as early as III Millennium BC, regular zinc production in China is not earlier than the 16th century AD and in India about 13th Century AD.

We discuss the evidence related with zinc and brass production in a historical perspective. Our main source of information for this chapter is the numerous papers by Craddock and his colleagues of M.S. University, Baroda. At the moment he is the most knowledgeable expert on early zinc.

Tracing the history of zinc, McNeil explains that in the early arsenical copper any residual zinc in a sulphide ore would have been substantially removed as a volatile oxide either during roasting or at a later stage during smelting, when fairly oxidising conditions were required to prevent too much iron dissolving in copper (McNeil 1990:73). He admits that certain ancient sources of copper, however, contained enough zinc to ensure that when smelted they produced low zinc brasses rather than copper. Thus Cyprus by about 2000 BC had become one of the major sources of copper in the Middle East, many copper artefacts have been found containing zinc in random quantities up to a maximum of 9 per cent. Most of the artefacts contain between 3 and 5 per cent zinc, presumably inadvertently introduced during the smelting of zinc-bearing copper ores (McNeil 1990:73).

Brass was certainly being produced in Asia Minor at an early date. McNeil reports some fibulae of the eighth to the seventh centuries BC, found in 1958 at Gordion, the ancient capital of Phrygia. These alloys we should now refer to as gilding metal rather than brass, since they contain only two per cent zinc. The sixth-century Greeks were beginning to use significant quantities of brass which at that time, because of its colour and rarity, was held in high esteem. In the fourth century brass was still being imported into Greece from Asia Minor. The original home of brass manufacture seems to have been Asia Minor where, according to Theopompus and Strabo, zinc in metallic form was being produced and used for brass making in the fourth

century BC. Irrefutable evidence that metallic zinc was known and used in the ancient world is also available in the form of a sheet of zinc, 6.5 cm long, 4cm wide and 0.5mm thick, dating from the third or second centuries BC.

By the first century AD, the Romans were making brass on a large scale by the cementation process even though metallic zinc was known and used in Athens three hundred years earlier. The Etruscans were producing statues from brass, in the fifth century BC. Those dating from the third or second century contain around 12 per cent of zinc. Egypt does not appear to have used brass before 30 BC, although Rome, by that time was very familiar with brass.

On the other hand, Hua Zeming (1997) claims that the earliest metal relics ever found in China are two brass artefacts from the Yang-shao Culture Ruins in Jiangzai Village, Lingtong County, Shaanxi Province. They date as far back as six thousand years ago, providing strong evidence that metallurgy germinated in China during that period. Craddock and Zhou (in press) however mention that the earliest occurrence of 2 brass awls excavated at Shandong Jiao Xian, Sanlihe, from the Longshan Neolithic culture levels dated to III Millennium BC. These awls are made of brass with more than 20% zinc. But they make it clear that these isolated examples did not play any real part in the development of brass in China. According to them brass was probably introduced into China by the Buddhist monks around 2000 years ago.

McNeil also recognises that metallic zinc was being produced by a refined distillation process at Zawar in Rajasthan in India, certainly as early as the fourteenth century AD and probably much earlier. He also mentions that this technique of zinc manufacture is described in several Indian alchemical words of the mediaeval period including the thirteenth century *Rasa Ratnasmuchchaya*. The word used in this document to describe the distillation process involved is *tirakpatnayantra*, which translated literally, means 'distillations by descending', so close to the Latin nomenclature that it is tempting to conclude that links existed at this period between European and Indian alchemical workers.

Despite the evidence to the contrary, McNeil holds the view that the Indian production of metallic zinc does not necessarily conflict with the idea that the secrets of zinc and brass manufacture were first discovered in Asia Minor. He says, "The evidence currently available, therefore, indicates that brass certainly, and probably also metallic zinc, were first made in Asia Minor before 800BC, and that by 700 BC golden coloured brasses were being imported by the Hellenese from regions such as Phrygia." He however admits that the manufacture of a natural brass alloy in Shantung province around 2000BC, and the early usage by the Chinese of a complex copper-nickel-zinc ore for bronze manufacture, seems more consistent with the idea that the identity of zinc as a metal, and the possibilities of brass as an alloy, were indigenous discoveries owing little to the Western world (McNeil 1990).

Craddock, who has devoted a life time to the study of ancient zinc, admits that brass, the alloy of copper and zinc, paradoxically has a history much longer than that of zinc itself. He explains that mixed copper-zinc ores do occur, and a mixed alloy could occasionally result adventitiously from smelting them. Thus some of the axes, chisels, awls etc. belonging to the Cienaga and Aguada cultures which flourished in the first millennium AD in the north-west of Argentina were found to contain up to 6% of zinc. Craddock however makes it clear that the two most frequently quoted examples of very early brasses, from TelGezer in Palestine, and from Vounous Belapais in Cyprus, both of Bronze Age date, have both now been shown to be using alloys of copper and arsenic, not brass (Craddock 1987/88: 225-245, 1987, 1989, 1995).

Craddock does concede that a very few bronzes containing several percent of zinc in addition

to tin are known from the early first millennium BC from the Middle East including fibulae from excavations at Gordion, capital of ancient Phrygia near present day Ankara in Turkey. Two of the bronze bowls excavated from the Assyrian city of Nimrud in northern Mesopotamia were found on analysis to contain several percent of zinc in addition to the usual tin content. This suggests that zinc may have already been present in the copper before deliberate alloying with the tin took place. There was sufficient zinc in these natural alloys to alter the appearance of the copper, and the smith probably recognised it as different, and prized it. There is some surviving literary evidence, including Biblical, thus when the children of Israel returned from captivity in Babylon and repaired and re-adorned the Temple, Ezra (8.27) speaks of various vessels, including "2 of copper fine as gold." Could this be the naturally occurring copper-zinc alloy encountered in the Nimrud bowls and elsewhere? The Assyrian cuneiform tablets speak of a special sort of copper called a "copper of the Mountain." Now this is significant because just at this time when the Archaic Greeks were learning so much from their Eastern neighbours there comes the first references in Greek to *oreichalkos*, literally "copper of the Mountain", as a metal quite distinct from ordinary copper or bronze. A few centuries later the term definitely referred to brass, but there is no certain proof at this period. The few references all refer to it as a rare, costly, shiny material usually used in the same context as gold. Thus Plato describing the principal temple of Atlantis says that the interior was covered with ivory variegated with gold, silver and *oreichalkos*, and goes on to relate that amongst the inhabitants of Atlantis gold was the most prized metal but that *oreichalkos* was the second, valued above silver.

Most of the references made to *oreichalkos* so far seem to be in either mythical or heavenly context, and it should be emphasised that contemporary with these fascinating if intangible references there are much more mundane inventories of temple offerings that also list items of *oreichalkos*. By the fourth century BC surviving literary evidence leaves one in no doubt as to the nature of *oreichalkos*, and a strong suspicion that it was being deliberately produced. The Greek geographer Theopompus in a work called the *Philippica*, now lost but quoted extensively by Strabo in his *Geography* of the first century AD. The text quoted by Strabo is as follows:

"There is a stone near Andeira which yields iron when burnt. After being treated in a furnace with a certain earth it yields droplets of false silver. This, when added to copper forms the alloy which men call *oreichalkos*."

Now the ancient town of Anderia lay in north-west Anatolia, in the region of Phrygia, near to Balia where mixed lead/silver/zinc ores were smelted in antiquity. One is immediately reminded of Gosal where, almost 2000 years later, the smelting of an identical mixed ore body produced droplets of a metal called counterfeitum or false silver. What else does one call a silvery metal, but which is not silver, coming from a silver mine? If the Strabo quotation is reliable and the interpretations put on it correct, then this would suggest that zinc was produced on a limited scale and used to make brass, and it would necessarily have been an expensive material in short supply (Craddock 1987/88: 225-245).

The identification of the "mock silver" from Anderia as zinc received a considerable boost in 1949 when excavations of the American School at Athens in the Agora produced a small roll of corroded zinc metal from a sealed context dated to between the fourth and second centuries BC. However this is almost the last we are to hear of zinc as a metal for many centuries, for by the beginning of the first century BC. Small denomination coinage of brass began to appear and its composition strongly suggests that it was made by directly reacting calcined zinc ore with copper, and would seem to herald the beginning of what came to be known as the cementation

process in Europe. There it was the usual method of making brass until the 19th century. In this process the zinc carbonate ore (smithsonite or calamine) was separated from any lead ore and then calcined to drive off moisture and render it more friable. It was then mixed with charcoal and placed in a closed crucible together with finely divided copper metal. The crucible would then be loaded into a furnace and heated to around 1000°C. The charcoal would reduce the ore to give zinc vapour. Many contemporary descriptions exist from the time of Pliny in the first century AD onwards. Those of the monk known to us as Theophilus in the 12th century and of John Percy in the 19th century are especially detailed (Craddock 1987/88: 225-245).

Craddock mentions that brass made by this process had no drawbacks, the amount of zinc which could be absorbed was limited (various authors quote figures, and it would seem that up until about 1500 AD 28% was the maximum, and thereafter about 33%). Recent experimental work by Headecke and Werner confirmed the 28% limit at a temperature of 1000°C, and the hundreds of analyses of Roman and Medieval brasses show that none exceeds 28%. The second drawback was the presence of impurities from the ore entering into the brass, particularly iron. Any iron minerals in the ore would be reduced to metallic iron, which could dissolve in the brass. This tended to discolour the metal and make it difficult to work. There were other problems with cementation brass as well. Dr. Watson in his *Chemical Essays*, written in the late 18th century, wrote that brass made of zinc and copper was "quite free of knots or hard places arising from iron to which other brass is subject, and this quality as it respects the magnetic needle renders it of great importance in making compasses" (Craddock 1987/88: 225-245).

ZINC IN CHINA

About the history of brass in China, McNeil says that brass dating from the period between 2200 and 2000 BC has been found in the Shantung province of China. Zinc then disappeared from the Chinese metallurgical scene until around 220 BC, in the Han Dynasty, when some of the bronzes began to contain small quantities of zinc varying between zero and about 5 per cent. Nickel also began to establish itself as a minor constituent of bronze at this time, when it seems reasonable to assume the Chinese had started to utilise a complex copper-nickel-zinc ore. Bronzes containing more than two per cent zinc were not made in China until the medieval times, at which time zinc in metallic form must have become available and would have been deliberately incorporated into the alloys (McNeil 1990).

Wagner refers to the claim of James D. Muhly (1986) to prove that "it can no longer be maintained that metallurgy began in China in ways radically different from those known elsewhere." A crucial point in his proof, however, is the rejection out of hand of all ancient copper-alloy artefacts which contain significant amounts of zinc: "It is quite impossible to accept the existence of brass artefacts from the time of the Yangshao Neolithic. The argument is thus clearly circular, for the only reason to reject these artefacts is that they suggest a radically different beginning for metallurgy in China than elsewhere. It must be repudiated on logical grounds alone. In addition Sun Shuyun and Han Rubin (1981) have shown empirically that such high-zinc copper alloys could be obtained by a primitive low-temperature smelting technique from mixed copper-zinc ores. In an addendum to a reprint of Muhly's article (1988:17) he takes note of this work and implicitly admits that his argument is fallacious" (Wagner 1993:31-32).

Craddock and Zhou (in press) however mention that the earliest occurrence of 2 brass awls excavated at Shandong Jiao Xian, Sanlihe, from the Longshan Neolithic culture levels dated to III Millennium BC. These awls are made of brass with more than 20% zinc. But they make

it clear that these isolated examples did not play any real part in the development of brass in China. According to them brass was probably introduced into China by the Buddhist monks around 2000 years ago, as noted above.

In China brass does not seem to have become common before the 16th century. There is no firm evidence for the production of metallic zinc before the beginning of the sixteenth century (Craddock 1987/88:225-245). The first brass coinage seems to have been in the Hong Zhi period in the year AD 1505, and contemporary accounts note that they were made from copper and 'new' tin, that is zinc. "The earliest good account of zinc production in China is in the Tien-Kung K'ai-Wu, from which it is obvious that the process owes nothing to the Indian process, but is derived from the local tradition of aqueous distillation with an internal condenser. Chinese coins analysed in the British Museum Research Laboratory show that brass only began to be used in the 16th century, but that by the late 16th century the zinc content was regularly over 30% suggesting that metallic zinc was used. Significantly the huge official technical encyclopaedias compiled in the 15th and 16th century all fail to mention zinc smelting. The first specific Chinese reference to the manufacture of brass by mixing copper and zinc metals is no earlier than the early 17th century. These books also suggest that zinc was then a new metal and that previously brass had been made by the cementation process. One might suspect that knowledge of zinc had spread to China from India, possibly via a Portuguese ship, but the process used by the Chinese, (and still apparently used in remote areas of the south-west of China) was completely different" (Craddock 1987/88: 225-245).

ZINC IN INDIA

Vijaya Deshpande also claims that metallurgy of zinc developed much earlier in India and China than in Europe (Deshpande 1996:276-279). Indian literary evidence of zinc smelting precedes that in China. Ancient mines and workings of zinc smelting are found at Zawar in Rajasthan where large scale production of zinc started from the thirteenth century AD. Excavations at Gui-Zhou region of Yun-han province show that zinc was produced in China in the sixteenth century AD. Earlier claims of Chinese and western scholars that China smelted zinc earlier than Ming dynasty have been refuted by new research by Chinese scholars. They have come to the conclusion that zinc smelting began in China in the mid-Ming dynasty i.e. the sixteenth century AD. Deshpande informs that according to the new research by the Chinese scholars there is a clear indication that zinc smelting began in China in the Jiajing period (1552 - 1566 AD) of the Ming dynasty. Zinc was exported to Europe in the middle of the seventeenth century AD from China under the name *totamu* or *tutenag*. *Tutenag* possibly has its origin in the word *Tutthanaga* - a name of zinc in South Indian languages. A seventeenth century Chinese author has written that *Tutenag* is a word from some foreign language. Thus there is textual and etymological evidence of transmission of ideas regarding zinc between the two countries. These facts together indicate that zinc was smelted some three centuries earlier in India than in China and these ideas were transmitted to China in the sixteenth century AD.

Deshpande says that some scholars have made a comparison of the traditional methods of smelting of zinc in India and China. It brings out the following facts:

1. The principle of the technique of traditional zinc smelting of both India and China is the same, viz. earthenware distillation of zinc and heating from outside; the temperatures are also comparable.

2. But methods for the condensation of zinc vapour were different. Zinc at Zawar in India definitely started by the thirteenth century AD (Deshpande 1996:276-279).

Craddock also feels that at first glance the Zawar industry is that most unusual phenomena, a fully-fledged technology with neither antecedents nor successors - and apparently no contemporaries either, for even within India it seems unique. In the search for the origins of the industry, the obvious starting points are the methods used to produce the only other volatile metal of antiquity - mercury. Heating the ore cinnabar (HgS) at about $700\text{--}800^\circ\text{C}$ in a vessel over which is placed another produced mercury at least 2000 years ago in both East and West. The cinnabar decomposed and the mercury vapour condensed in the upper vessel and ran back down to be collected. The Indian process was slightly different; the ore was smeared over the inside of the upper vessel, which was itself heated causing the mercury formed to run down into a lower vessel to be collected beneath water - another example of *Tiryakpatana* or downward distillation. There, though, the similarity with zinc smelting ends. Zinc required a much higher temperature and the total exclusion of air. The form of the *kosthi* furnace for holding the retorts seems to have been inspired by the common pottery kiln. The arrangement is of course totally different: instead of a fire beneath to heat the pots stacked above through the perforated floor, in the *kosthi* the fire and retorts were in the upper chamber and the zinc was collected beneath. Thus the installations at Zawar seem to be a combination of the principle of mercury smelting and the form of the pottery kiln. Together, they led to one of the most advanced metallurgical operations of the mediaeval world. (Craddock 1987:183-191).

Zinc (wo-ch'ien, lit. Japanese lead), a term of recent origin, does not appear in ancient books. It is extracted from smithsonite (calamine) and is produced primarily in the T'ai-hang Mountains of Shansi, followed by Chingchou (in Hupei) and Heng-chou (in Hunan).

This evidence is reinforced by analysis of the Chinese 'cash' coinage. Brass begins only in the 16th century, but already by mid-century some of the coins have such a high zinc content that they must have been made by mixing copper and zinc metals. Thus it would seem that sometime in 16th century, in both Europe and China, zinc made its first appearance as an imported metal. Could the common source be India and the common carrier the Portuguese, the first to open up the oriental trade? It is often forgotten in Europe that those voyages were not just Europe-India, but Europe-India-China-India-Europe and those fresh cargoes were loaded and sold at each port.

By the mid-17th century there were detailed descriptions of the zinc making process. The Chinese process is very different from the Indian process, and is an adaptation of the traditional Mongolian still, which has the condenser and collecting vessel both inside the retort itself; this process still operates in remote parts of China. The ore and coal are placed in the metre-tall retorts; the collecting vessel or saucer is inserted above towards the top, and the lid, which acts as condenser is lightly fitted on. The retort is then placed in the furnace with the upper third protruding. Inside the retort the coal reduces the zinc ore, which condenses on the lid and drips down into the saucer. By the end of the 17th century Chinese zinc made by this process had already entered international trade and was even being imported at Madras as well as in Europe (Craddock & Zhou 1998).

Thus, Craddock explains that there is a continuous thread of development leading from the *kosthi* furnaces at Zawar through to the present day. Zawar can lay claim not only to the earliest high temperature distillation process in the world, but also to being the direct ancestor of all

such techniques in use today. The Zawar process was certainly one of the most sophisticated and technically exacting process developed in the mediaeval world. One hesitates to use the term 'pre-industrial', for surely this process, with its appreciation of scientific techniques, and learning towards mass production, should properly be considered as an early example of an industrial process in the modern sense. The origins of modern chemical and extractive industry are spread over a longer period and through far more of the worlds than people in Europe sometimes care to admit (Craddock 1987:183-191).

The earliest firm literary evidence for the production of metallic zinc on a regular basis comes from India (Craddock 1987/88:225-245). There are references to burning a metal, *rasa*, to produce an eye salve, which should refer to zinc, placing its use in the last centuries of the first millennium BC. The *Rasaratnakara*, ascribed to Nagarjuna, the great Indian scientist who lived in the fourth century AD, but which was probably compiled in its present form in the seventh or eighth century AD, describes both the production of brass by the familiar cementation process, and of metallic zinc.

Furnaces very similar to the Koshthi described above have been found at the ancient mines of Zawar in Rajasthan, buried in enormous heaps of used retorts. The excavations at Zawar uncovered several almost intact banks of furnaces. The furnaces at Zawar were the industrial version of those outlined in the *Rasaratna-samuchchaya*, with banks of between three and seven furnaces, and each furnace held 36 retorts (Craddock 1987:183-191).

Detailed studies of the spent retort charges and the refractories suggest the conditions in the retorts were intensely reducing with temperatures of between 1100 and 1250°C. Studies on the depth of vitrification of the furnace walls would suggest the process was at maximum temperature for the order of 5 hours, which fits remarkably well with the duration of 4 hours claimed in the description given in the 1840s by the last inhabitant who remembered the process (Craddock 1987:183-191, 1987-88, 1995; Craddock et al 1989, 1985).

Bhatnagar & Gurjar (1989:5-8) explain that the problem of producing Zinc as a metal, arises due to its volatility (boiling point 907°C) when using traditional simple shaft furnace, in which smelted metal settles down at the bottom as ingot, whereas zinc ore produces zinc vapour which instantly gets reoxidized in the flue and is lost. Therefore zinc could not be isolated from its ore in the West till 1736 AD, when W. Champion first produced metallic zinc from ore at Bristol, UK. The ancient smelting method had resolved the problem by smelting zinc ore through distillation and condensation technique using clay retorts.

In India, smelting of zinc is known since centuries. Various zinc smelting processes were described in the Sanskrit work of medicinal chemistry and alchemy, viz., *Rasarnavam Rastantram* (500-100 BC), *Rasratnakar* (2nd century AD), *Rasprakash Sudhakar* (12th Century AD) and *Rasratnasamuchchaya* (late 13th century AD) etc.

Craddock et al (1985:45-52) have mentioned that in many early smelting processes it was the practice to bind the ground and calcined ore into balls with some sticky organic material - cow dung was an effective medium used in the 19th century by copper smelters at Khetri, to the north of Zawar. Having the ore and fluxes in discreet balls should stop the charge falling out of the retorts when they were initially inverted in the furnace and at the same time, would facilitate the escape of the zinc vapour formed during firing. The conical clay condenser head and neck was next firmly luted onto the retort with clay so as to leave no air gap. In order to create a clear route for the zinc to escape from the retort into the condenser head a stick was pushed up the condenser through the sticky charge and allowed to burn out, leaving a central

hole running the length of the charge. These holes (approximately 10-mm diameter) can still be seen running through the charge in some of the retorts, and one has been found with part of the charred stick still in place. The charged and sealed retorts were now ready for firing.

The exterior walls are of regular coursed bricks, occasionally replaced by a suitable fragment of refractory or stone, standing eight courses high from the plinth of stones on which the furnace is based to the rim. The area in front of the furnace was paved with large flat bricks. The interior of the furnace walls is much less regular and often large gaps in the brickwork were just filled with clay and refractory fragments. The inner face of the furnace and chamber beneath were roughly plastered with about a centimetre thickness of clay. Each distillation unit was in two parts, a lower condensing chamber, square in plan and separated by perforated bricks from the upper, main furnace, chamber, which was in the form of a truncated pyramid. The internal dimensions of the furnaces (taken from furnaces 3 and 4) at the base was 660 mm x 690 mm, being slightly wider across the side with the entrance to the lower chamber.

The division between lower chamber and the furnace proper was made by four of the perforated bricks (55 mm thick), fitting closely together and resting (but not mortared) on a projecting brick ledge at the sides with a single clay peg providing support in the centre. The use of a peg as necessary to reduce obstruction to a minimum as the lower chamber, which contained the collecting vessels, was entered through just one small opening. Each of the perforated bricks had 9 large (35 mm diameter) holes to accommodate the condenser necks, and 26 smaller holes (plus 9 shared with neighbouring bricks) for the passage of air into the furnace and for ash to drop through (Craddock et al 1985:45-52).

On both sites, the retorts were loaded vertically into the truncated pyramid chamber of the furnace. The retorts rested on the perforated bricks with the condenser necks protruding down into the cooler chamber below. The retorts were fired in situ with the charcoal around and above them. There is no evidence for tuyeres or bellows but the front face of all the furnaces is missing. The condensed zinc would have dripped down into the now missing collection vessels placed beneath (Craddock et al 1985:45-52).

Describing the process, Craddock says that the temperature and reducing conditions within the retort-condenser system were critical. Inside the retort the temperature had to be in the region of 1,100°C for the reaction to proceed satisfactorily, but if it had been very much higher the softening clay retorts would have collapsed altogether. In the short distance along the condenser neck the temperature had to drop below the boiling point of zinc (913°C), but remain above the melting point (432°C) to prevent solidified zinc blocking the tube. The highly reducing conditions had to be maintained through the system otherwise the zinc vapour would reoxidise in the condenser. (The positive pressure of carbon monoxide produced in the retort from the reduction of the zinc oxide must have helped exclude air.) (Craddock et al 1985:45-52).

Maintaining these conditions for one retort would have been exacting but the same conditions had to be simultaneously maintained over 36 retorts in each furnace irrespective of whether they were in the centre or a corner. This must rank as one of the most skilled and sophisticated operations known from the pre-industrial world. In fact in its appreciation of scientific technique, and large scale production it is already bordering on the industrial age and, as is demonstrated below, the Zawar process is probably the immediate ancestor of all modern high temperature distillation processes (Craddock et al 1985:45-52).

Craddock explains that the degree of vitrification of the retorts suggests temperatures in the 1050°C-1150°C range, which compares well with the required temperature of 1100°C.

Zink Mines & Mining in India

Let us now have a look at the occurrences of zinc minerals in India. Chakrabarti and Lahiri (1996) have reported the following zinc mines, though Rajasthan remains the main source.

Kashmir and the adjacent areas, including Afghanistan : Buniyar in Baramulla district: Ghor, Kandahar, Paktya Herat, Farah, Bamiyan, Ghazni, Takhar and Badaskan in Afghanistan.

Himachal Pradesh : Bara Shigri glacier in Lahaul-Spiti and Uchich in Kulu.

Uttar Pradesh : Askot, Khanayun-Galpakt-Kimkhet in Nainital-Pithoragarh; Dudhi in Mirzapur.

Madhya Pradesh : Kundartola-Belangi in Surguja and Chandidongri in Durg.

Gujarat : Ambamata, Kui-Chitrasani, Omlikamala in Banaskantha, Banejnes in the Gir Forest in Junagadh and Vadek-Champaner belt in Baroda and Panchmahals.

Bihar : Amjhore in Shahabad and Golgo in Hazaribagh.

West Bengal : Gorubathan in Darjeeling, Kushbani-Gohalbaria in Midnapur-Purulia.

North-eastern region : Potin and Rub in the Ranga valley in Arunachal, Umpyrtha, Barapani-Tyrsad in Meghalaya, and Nagaland.

Andhra Pradesh : Agnigundala in Guntur, Zangamrajupalle, Gollapalle in Cuddapah, Chelima in Kurnool, Pacherla, Venkatapalem in Khammam.

Tamil Nadu : Mamanadur in South Arcot.

Rajasthan : Zawar, Ajmer, Jahazpur, Malikhera-Devpura-South Dedwas-North Dedwas-Samodi-Tiranga in Eastern lead-zinc zone, Jasma-Rewara-Karor, Kalahudi-Bethumni, Banswara, Ajari, Basantgarh, Pipela-Watera.

Among the old workings for zinc, the Zawar complex of Rajasthan is the most famous. Impressively abundant traces of old workings extend all over the 25 km mining belt and go down to a depth of 90 m below surface. It is claimed that the Zawar miners went upto depths exceeding 150m. Smelting debris covers the valley leading to the mining area at Zawar and clay retorts for zinc smelting. The ore at Zawar is a mixed sphalerite, ZnS/galena, PbS deposit.

Tiwari & Kavdia (1984:81-87) have reported that the richest deposit from Rampura-Agucha Zinc-Lead Deposit is located 1.5-km north-east of Agucha village in Bhilwara District, Rajasthan. It is the single largest and richest deposit of the country. Ancient mine workings, vast slag-spread and mine debris in the vicinity of the deposit bear testimony to ancient mining and smelting activities. Ancient mine workings occur as open excavations, trenches, shafts and pits. The shafts & pits were put at preferential locations for entry, and drives and raises followed ore zones. Evidence suggests that ancient miners concentrated on mining of lead rich ore in and around the deposit. Most of ancient mining was confined to 80 m depth from the surface but a few attain depth up to 125 m. Deep seated ground water conditions, during dry and draught seasons, might have made the deep ancient mining possible. Slag pieces found in the archaeological mounds along with articles related to pre-Maurya and Maurya period dates the ancient mining prior to 3rd century BC. Agucha Village (N 25° 50'; E 74° 44' 15") is located 15 km. south-east of industrial town of Gulabpura and is connected with the town by all weather road via Hurda. Gulabpura is situated 65 km. north of Bhilwara and is 75 km. south of Ajmer on Bhilwara Ajmer state gauge line of western railway linking Ajmer with Khandwa via Chittorgarh.

Dating

Samples of wood from the Zawar Mala mine in what is predominantly a sphalerite deposit gave

^{14}C dates of 170 ± 50 BP. The earliest dates for Zawar are from the mines at Mochina and Zawar Mala, which show that zinc, and some lead was being mined between the sixth and first centuries BC. The earliest dates we have for zinc distillation are from a white heap, which is of the 12th century AD (Craddock 1987: 183-191).

Bhatnagar & Gurjar (1989:5-8) report that the timber ladders are 3 to 6 m in length and 0.6 to 1.0 m in width. Radiocarbon age determination (uncalibrated) of a piece of haulage scaffold yielded an age of 2350 ± 120 years before present. They also say that the radiocarbon age determination of a portion of a launder yielded an age (uncalibrated) of 2180 ± 35 years before present. These two radiocarbon ages suggest that the operations in Zawar were probably the earliest zinc mine in the world.

SUMMARY

Despite the very early occurrences of accidentally produced brass both in China and West Asia, deliberate brass production was very late. The Zawar area of Rajasthan, in India, seems to have stolen a march globally in the earliest production of zinc. The distillation technique of zinc production goes back to the 13th Century AD and possibly reached China from India in the 16th Century.

In the next chapter we will discuss the alloying metals like arsenic, tin and lead.

CHAPTER 13

TIN, LEAD AND ARSENIC

CONTENTS

- TIN
- LEAD
- ARSENIC

In this chapter we discuss the three most important elements used in alloying copper: tin, arsenic and lead. Tin and arsenic are used to improve the hardness and malleability of copper and lead improves the fusibility and casting properties.

TIN

Introduction

Darling (1990) states that the most abundant and significant tin mineral is cassiterite, the oxide SnO_2 , which varies in colour from brown to black. Cassiterite is noteworthy in that its high specific gravity of 7.1 is comparable to that of metallic iron, and also because its hardness is comparable to that of quartz, so that it is highly resistant to abrasion and tends to concentrate in gravel and alluvial deposits.

Four cassiterite mines have been located in the eastern Egyptian desert, one of which was accurately dated from inscriptions associated with the Pharaoh Pepi II to around 2300 BC, approximately 500 years after the appearance of the first Sumerian bronze. Copper artefacts, containing significant quantities of tin were not produced in Egypt before the Fourth Dynasty, around 2600 BC, and the true Bronze Age in Egypt, when artefacts containing 8-10 per cent of tin were produced, did not begin until 2000 BC.

It seems logical to assume that at some time around 3000 BC, the concept of bronze manufacture was acquired by the Sumerians, either by trade or conquest, from a region outside Mesopotamia where tin was a readily available commodity. Between 2600 and 2500 BC supplies of tin to Mesopotamia appear to have been interrupted, many of the copper artefacts dating from the Second Sumerian Revival being simple arsenical copper containing little or no tin. The shortage of tin, whether it was caused by natural disasters or by political upheavals, was not prolonged, however, and after about 2500 BC the use of 8-10 per cent tin bronzes expanded rapidly throughout the Middle Eastern world (Darling 1990).

After about 3000 BC, however, the arsenical content of Middle Eastern copper artefacts begins to decline, perhaps because of the progressive exhaustion of rich, accessible arsenical copper ore deposits. Artefacts containing small quantities of tin made their first appearance during the early stages of this decline although the quantities involved rarely exceeded about 2.5 per cent.

Such alloys, which first appeared in Iran around 3000 BC, did not reach regions such as England and Brittany, on the outer fringes of civilisations, until about 2200 BC (Darling 1990).

These low tin bronzes must be regarded as the precursors of the later true bronzes containing 8-10 per cent of tin. They presumably emerged accidentally, either by the smelting of copper ores, which contained tin minerals, or by the use of tin-bearing fluxes.

Darling thinks that if the possibilities of alloying had been grasped at this stage, it seems logical to assume that they would have been progressively exploited. No evidence for such a gradual evolutionary process has been found, and virtually no artefacts containing more than 2.5 per cent of tin have been identified which antedate the sudden emergence of the 8-10 per cent tin bronzes in Sumer between 3000 and 2500 BC. It would appear that the copper workers of Ur suddenly discovered or acquired the concept of alloying, and rapidly developed and optimised the composition of bronze. This sudden leap forward cannot be separated from the rapid expansion of trade in the Middle East around 3000 BC, since it seems improbable that the significance of tin as an additive to copper would have first been identified in a region where its ore was not indigenous.

Early Bronze Age developments have also been found in southern China, Thailand and Indonesia, where alluvial tin and copper ores are sometimes found in close association.

The earliest tin bronzes so far identified appear to date from the fourth millennium BC and were found in 1930 at the site of Tepe Giyan, near Nahavand in Western Iran. The sudden appearance of true bronzes at Ur around 2800 BC, and in Amuq near Antioch in Turkey, about 3000 BC would be consistent with the view that the concept of bronze manufacture originated in a community such as Tepe Giyan, in the Persian highlands, during the fourth millennium, then subsequently moved southwards to Sumer and the Persian Gulf, and westwards to the Mediterranean seaboard, during the third millennium.

The other sources for tin are Khorasan, Kara Dagh and the area between Bukhara and Samarkand. It thus appears that this scarce metal could only be obtained and used in some significant quantity when regular trade was established between the Indus and Central Asia. This is precisely why tin-based bronze objects at Mohenjodaro came in larger numbers from the upper levels (Agrawal 1969-70: 16). The tin that went from Meluhha to Mesopotamia also probably originated in Central Asia (including northern Iran and Afghanistan). The same may be true of silver and lead. As noted earlier, only Iran and Afghanistan could supply silver and lead to the Indus. This is also evident from the frequent use of silver at Mohenjodaro and Harappa. However, Rajasthan and Gujarat may have obtained their silver from the Ajmer and Zawar mines of Rajasthan. The quantities may have been limited as the people there used it sparingly (Asthana 1993).

Sources of Tin

Cassiterite, when pure, contains 78.6% tin. But vein ore is so mixed up with quartz that only 0.2 to 2.0% tin is found in it. In these veins cassiterite is found as dark brown or black bands. Generally such stanniferous veins are found in granitic rocks which on disintegration give away their cassiterite in the river streams along with alluvial gravels and it is called stream tin. Though

the vein ore is poor in tin, washing action of the stream concentrates it. Stannine (containing 25% tin) is rare in the Occident and the complicated technology required to use it rules out its use in antiquity. The main tin fields of antiquity are the following:

Asia Minor: Darmanlar, Murad Bagh and Kastamuni.

Caucasus and Transcaucasia: Belaia river basin, region between Elburz and Terek, Gori region, Sharopani, Karadagh and Karadagh mounts.

Persia: Kuh-i-Sehend near Tabriz, near Astrabad and Damghan, Kuh-i-Benan.

The tin belt extending from Burma, Malaya to Billiton.

Indian Tin Ores

There is no production of primary tin even now in the country. Tin ore deposits are known from Hazaribagh, Ranchi, and Gaya in Bihar, Banaskantha in Gujarat, Dharwar in Mysore and Bhilwara in Rajasthan. But nowhere are they economically exploitable. There are no indications of old mining, as it is more likely that the stream tin was used for alloying.

Chakrabarti & Lahiri (1996) report several polymetallic deposits. In Bihar, for example, copper, lead and zinc occur together at 5 localities in Bhagalpur, 12 localities in Hazaribagh, 1 locality in Munger, 3 localities in Palamau and 8 localities in Santhal Parganas. Such polymetallic deposits are known all over the subcontinent and are likely to have played some role in the shaping of the elemental composition of different ancient Indian copper objects.

The known occurrences of cassiterite or tin ore in the subcontinent are in (1) Hazaribagh, Ranchi and Gaya districts of Bihar; (2) the Dambal hills of Dharwar; (3) Kadavur and Ururakarad in Tamil Nadu; (4) Hosainpura in Banaskantha and Jambughora east of Champaner in Gujarat; (5) Bhilwara in Rajasthan; (6) Bastar in Madhya Pradesh; and (7) perhaps in Almora and Pithoragarh of U.P. (for a detailed review see Chakrabarti 1979 and Agrawal & Kharakwal 1998).

Summarising the evidence, Chakrabarti & Lahiri (1996) say that Bastar has a commercially exploitable deposit, and as early as 1881, V. Ball drew attention to the prevalence of pre-industrial tradition in tin smelting in this area. This mineralisation in Bastar exists 70 km south of Jagdalpur in the Kolab river valley. Ball wrote: "A communication received from Mr. Vanstavern by the Geological Survey of India suggests the possibility of the occurrence of tin stone in the Bastar state. A Gond from a village called Papagudem, who wore a tin bracelet, was seen by Mr. Vanstavern at Dumagudiem. On being asked about it he said that the metal had been made in his own village from black sand resembling gun powder which was found there. The name of the village is supposed to be derived from Papamu which means tin."

The second such report comes from the Hazaribagh-Giridih and Ranchi districts of Bihar. In Ranchi, the presence of trenches and pits in the cassiterite-bearing Paharsingh locality suggests pre-industrial exploitation of tin. The report from the Nurungo locality near Giridih, which dates from 1874, is clear.

During the time it was worked, the ore after being brought to the surface was broken up while still fresh (as it hardened considerably after exposure). The pounded ore was then placed in a basket and washed by hand, which means most of the lighter impurities, chiefly quartz and feldspar, were removed. Subsequently, after drying it was sifted in a winnowing basket to separate the remaining.

Although Southeast Asia is well known as the site of the world's richest tin deposits, little geological research has been done from the point of view of prehistoric metalworkers. Estimates

of reserves are traditionally unreliable in the tin industry, but all authorities agree that Southeast Asia with Yunnan contains more than half of the world's tin. The northern mainland and southern China contain a fairly large number of scattered deposits. All the rest of the tin is concentrated into a single belt that runs from the eastern side of central Burma down through the Kra isthmus and the Malay peninsula to the island of Singkep, Bangka and Belitung. Adjacent parts of Sumatra have a few small deposits and the whole of the Philippines have none at all (Bronson 1987).

LEAD

Native lead is rarely found. Its sulphide, galena, is fairly abundant and would have been instantly recognisable by primitive man because of its lustre and high density. When exposed at an outcrop, galena weathers and oxidises. Anglesite is the sulphate of lead; it is a mineral formed during the intermediate stages of this reaction process, which generally concludes, with the formation of cerussite, a lead carbonate. Galena usually contains between 0.03 and 0.1 per cent by weight of silver.

Darling (1990) tracing the history of lead says that at 6500 BC horizons in the ancient Anatolian mound of Catal Huyuk, beads of fused lead have been found in close association with hammered beads of native copper. It appears that lead must have been extracted from its ores at an earlier date than copper, especially in view of the low melting point of lead and the ease with which its oxide can be reduced. Metallic lead has been found in Iraq, in a 6000 BC context at Yarim Tepe, and at the fifth millennium sites of Anan and Hissar III in Iran and Naqada in Egypt. The earlier evidence of lead being used for aesthetic rather than practical purposes is provided by an Egyptian figurine 5 cm high, dating from about 4000 BC (now in the British Museum). It is unusual in having been carved from a solid block rather than being cast to shape; the lead is of high purity.

Lead artefacts of the third and second millennia BC include spindle whorls, weights for fishing, and wire which appears to have been used for repairing pottery. Lead weights, based on a unit module of 61 g, have also been found throughout the Aegean in Middle and Late Bronzes Age contexts. Shapeless lumps of lead were found in the layer of the Hissarlik ruins corresponding to the period between 3000 and 2500 BC (Darling 1990).

Lead Minerals in South Asia

Among the alloying agents of copper, lead is the most abundant. Summarising the occurrences of lead, Chakrabarti & Lahiri (1996) give the following sites: "In Baluchistan, lead occurs between Kalat and Panjgur and in Khuzdar of the Sarawan district. Charles Masson (1975 rep. II: 43) reported lead smelting for bullets in the Khuzdar area. Afghanistan (Reedy 1992:245) has concentrations of deposits in the provinces of Ghor, Uruzghan, Bamiyan, Loghar and Ghazni, with evidence of pre-industrial mining and smelting in Talah in Uruzgham and in the Koh-i-Daman area of Ghorband in the Hindukush foothills. Locally processed lead was reputedly sold in Kandahar in the 19th century. Kashmir seems to have a promising source in the Zaskar area of Ladakh (Raghunandan *et al.* 1981: 185 ff) and in the Doda district. In Jammu, there is a mineralised zone in Udhampur. Old workings exist in Doda. The Bara Shigri glacier in the Lahaul-Spiti section of Himachal Pradesh has a zone of lead mineralisation, and the Kulu-Bijnar area has four reported occurrences, among which the one in the Parvati valley shows silver mixed with lead, *i.e.* argentiferous galena (Raghunandan *et al.* 1981: 189-90). The U.P. Himalayas possess

extensive sources at Askot (Pithoragarh), Galapkot-Kimkhet (Naini Tal-Pithoragarh), Birgana (Pauri-Garhwal), Shish-khani and Chhanapani (Almora) and between Dehradun and Rishikesh. Old workings occur in Dewaldhar, Shishkhani and Baldeo hills of Almora. Mirzapur is the second region in U.P. to have lead, the important locality being Dudhi (Raghunandan *et al.* 1981:190). In the Northeast, lead exists in the Ranga valley of Subansiri (Arunachal Pradesh), Umpyrtha of the Shillong plateau and Barapani-Tyrsad of the east Khasi hills in Meghalaya. Tosham in Haryana has some lead, but is far more extensive in the neighbouring Rajasthan where the main areas are the Ajmer lead-zinc zone, the Jahazpur lead-zinc-copper belt, the Pur-Banera belt, the Zawar lead-zinc belt, the Dariba-Rajpura-Bethumni lead-zinc belt, the Basantgarh-Deri belt, the Rampura-Agucha zone, the Jasma-Rewara-Karor belt, the Salam-pura-Kochriya area, the Banswara lead-zinc belt, and the relatively less significant Basantagarh area (Raghunandan *et al.* 1981: 64-65). Many of these areas show old workings, the most noticeable being from Zawar and Rampura-Agucha (Tiwari and Kavdia 1984)".

Ancient mine workings in the Rampura-Agucha area are visible on the surface as old trenches and pits, as underground drifts, raises, inclines and stopes in exploratory mine development, and in ancient shafts which are now being used as irrigation wells. Also extensive underground old workings have been discovered during intensive diamond drilling carried out for detailed exploration of the deposit. The deposit has been drilled at 50 m spacing. All the old workings intersected in various bore holes are projected on longitudinal vertical plane. The underground old workings are localised in two regions.

Tiwari and Kavdia (1984:84-85) conclude that it has become amply clear that ancient miners did not work the zinc rich deposit extensively. The deposit was worked towards its narrow northern extremity, where detailed exploration has established higher concentration of lead mineralisation and also at preferential locations in the south. The bulk of the ancient mining was confined close to the ore body in the hanging wall where sporadic occurrences of pure galena veins, pockets and minor disseminations are known to occur, mostly in calc-granulite bands and lenses. The above facts stress the preference of ancient miners for lead to zinc mineralisation.

They observe that the ancients appear to have first attempted mining of galena rich northern extremity of the deposit by open pitting. Also, at wider sections of the ore body in the south, pitting was done at preferential locations for entry and rich ore mineral (galena) patches were followed by trenches and narrow underground drives, inclines, winzes and raises. During the course of the mining, the ancients might have noticed pure galena veins in the hanging wall, close to the ore body and later mining activity was, therefore, shifted to the hanging wall for each galena pockets and veins. In the hanging wall, close to the ore body series, inclines and vertical shafts were dug for entry. The intersected galena shows were followed by underground openings as drives, inclined raises and winzes while the encountered rich galena pockets were mined. The probing, crosscutting and driving appear to have been done along crushed shear zones and along open master joints. Most of the ancient mining was confined up to 80 m depth below surface. However, in some parts, the old workings extend up to 125 m depth. Regular mining operation to such depths without efficient dewatering equipment and system is difficult to conceive. However, deep seated ground water conditions could have made the deep ancient mining possible during dry and drought seasons. The slag occurs as thin black cover on the ground and only at a few locations small heaps are observed. Four composite samples of slag were analysed for lead, zinc, iron, copper and silver. The analysis indicates high concentration of lead in the slag. The fact again establishes that the ancients mined lead rich zones in and

around the deposit. There is a large archaeological site on the bank of the Mansi river near Agucha. It was possible to pick up sherds of c. 200 BC from the Agucha slag dumps. The Agucha mound which is about 1 km long goes back to the pre-Mauryan period, and there is no doubt about the relationship of this site with the local mining of ores (Tiwari & Kavadia 1984).

C.G. Dixon (1831 in Chakrabarti & Lahiri 1996) witnessed pre-industrial lead mining in operation in the hills near Ajmer. There openings were at the height of 100 to 350 feet (30-100 m) from the level of the plain, spread for about 300 yards (270 m). After the colouring of the rocks showed presence of, or proximity to, the ore, a perforation was made in the rocks, sometimes unsuccessfully. The basic task was to follow a vein and when a number of veins showed up the major one was followed leaving the minor ones for the future. The opening was not expanded more than what was necessary for a man to move on his hands. There was no system to remove underground water and the miners generally removed themselves to the upper ground once water was encountered. Particularly hard stretches of rock were calcined by fire. This was usually done at the end of the working day so that miners could begin work at the spot next morning. The mining implements consisted of two or three hammers of different weights, a few chisels or wedges edged with steel and some one-armed picks. The miners used to enter the mines about sunrise, divesting themselves of "every attire of clothing" and carrying a small lamp in their hands. The ore was crushed before being put in bamboo baskets, which were then transported to the mouth of the mine in the following manner (Dixon 1831:LS1): "As the gallery is not sufficiently high to allow the workmen to stand upright, they sit on their haunches, arranged in a row, from 4 to 12, according to the capacity of the mine, and pass the baskets from one to another. When the whole has reached the foremost man, they move upwards, and again arrange themselves. This is continued until the mouth of the mine is attained. The disputes regarding the ownership of a vein were settled by the miners' council by erecting a wall of loose stones at the points of contact. The meeting of channels also helped ventilation for which no special provision was made otherwise. The lead miners of Ajmer did not spend more than 3 to 4 hours a day in the mines and looked very healthy."

In Gujarat, lead has been noted in Junagadh (in the Gir forest), Baroda (Khandia village) and Panchmahals (Jamla Chowki-Kadwal). Old workings occur in Panchmahals (Shekar and Mukul 1972; Chatterjee 1972: 149; Vemban and Yellur 1972).

In Madhya Pradesh, the lead occurrences are in Jabalpur (Imalia-Bhula-Nawalia), Gwalior (Antri, Kurnool, Bagesh-Gijora), Surguja (Bhelai-Dhorpur, Kundarola-Belangi), Shivpuri (Andar), Tikamgarh (Bahadurpur), Hoshangabad (Joga) and Durg (Chandidongri) (Raghunandan *et al.* 1981:48 ff). Old workings are reported as well (*cf.* Roy Chowdhury 1955: 42-43).

The lead bearing districts in Andhra Pradesh are Chittor (Voddavaripalle), Cuddapah (Zangamrajupalle-Varikunta, Nagasanapalli, Gavulabhavi, Ankireddibhavi), Guntur (Agnigundala, especially the Bandalamottu and Dhukonda blocks), Hyderabad, Khammam (near Niradu, northeast of Jestaipalle, Rudramakota), Kurnool (near Chelima railway station, Pedda Adisarlapalle, Chintagunta, Mallapalli) and West Godavari (Marlagudem) (Karunakaran 1975: 22).

Old Workings

Old workings occur in various places. The main early workings at Gadageribodu are mainly quarries at 10-20 m width and a few metres deep extending for about 150-250 m strike length. At Varikunta the most important group of ancient workings is found in the Gavulabhavi area. These workings extend for a strike length of 1,200 m (Rao and Rao 1977:88). "The ancient workings consist

of linear pits and trenches, shafts, and inclines developed laterally underground in the form of drifts and slopes dipping at steep angles to the east in the eastern part and to the west in the western part. One of the surface diggings extends for about 280 m along the strike. The main underground mine had been developed for a length of over 100 m, the initial 30 m being a partly stoped drive, followed by two parallel drives interspersed with stopes and connected by cross-cuts at regular intervals. The deepest accessible stope in this mine is approximately 90 m below the surface" (Rao and Rao 1977).

In Karnataka, lead is found in Chitradurg (Gonur-Gollarhatti, Ingladahalu, Kunchiganahallu, Kurubaramaradikere), Mysore (Arothekoppal) and Shimoga (Banavalli and Karagevalli) (Karunakaran 1974:20). In Tamil Nadu, lead occurs in Madurai (Jusiyar-Alangulam), North Arcot (Alangayam-Andiyappanur) and South Arcot (Mamanadur). In Bihar, the lead bearing districts are Bhagalpur (Baghmari, Bhorsar, Dudhijor, Ganaura, Karda, Pirrah, Chandaipatti, Rikiha-Rajdah, Kajra-Gohra, Garbaran, Bhoga, Badladh, Bhagro-Bajra-Jhilua, Bhusia-Bhadaria-Duarsar), Hazaribagh (Golgo, Bengabad, Bishenpur, Chandio, Karkarkudar, Jhalakdiha, Ganganpur, Jhagrudih, Damgi, Aunragaro, Kurkipahari), Santhal Parganas (Belbathan, Toolsitanr, Charkipahari, Bodh Bandh, Panch Pahara, Sankara) and Shahabad (Amjhore pyrite deposit) (Raghunandan *et al.* 1981:163).

In Orissa, lead occurs in Sundargarh (Sargipalli, Kiringera, Panposh), Bolangir (Badipara, Dongarmunda, Dungripalli, Limpara, Saintala), Kalahandi (Baminimunda, Teresingha, Khairmal, Pipal Padar), Sambhalpur (Kendumunda, Bhanjhalpali, Gangajal) and Mayurbhanj (Pittabata, Champagarh, Bhunjobani, Mundabani) (Raghunandan *et al.* 1981:170). In West Bengal, Gorubathan in Darjeeling is the most important deposit with its strike length of over 7 km. But there are lead occurrences in Midnapur (Belpahari and Gohalbaria) and Purulia (Kushbani, Bandhdanga, Beldih, Biramdih) as well (Raghunandan *et al.* 1981:175 ff). Finally, Rangpo and Pakhyong in Sikkim possess some lead (Raghunandan *et al.* 1981 :171, 174).

ARSENIC

When an awareness that many early copper artefacts were in fact dilute alloys of arsenic in copper began to develop after 1890, it was thought that arsenic had been deliberately added to improve the mechanical properties. Bertholet, in 1906, was the first to demonstrate that the concept of alloying would have been unknown when these artefacts came into general use by the ancient Egyptians. The earliest Egyptian artefacts of arsenical copper were produced around 4000 BC in Predynastic times. In addition to arsenic, these early weapons contained around 1.3 per cent of nickel.

In the cast conditions, arsenical copper is only marginally harder than pure copper, although its hardness increases very rapidly as a result of cold working. This must have been a factor of great importance in the Bronze Age when edge tools were invariably hardened and sharpened by hammering.

When arsenical copper ores are smelted with charcoal, arsenic has little tendency to escape because it is held in solution by the molten copper. Similarly, when copper alloys containing up to 7 per cent of arsenic are melted in a crucible under reasonably reducing conditions, little is lost. Arsenic oxide, however, is very much more volatile than elementary arsenic, and toxic fumes must certainly have been emitted in copious quantities during the roasting of copper sulphide ores containing arsenic. Since sulphur dioxide fumes would also have been given off in vast quantities, the additional health hazards caused by arsenic would not, however, have been separately identifiable. Certainly nothing appears to have inhibited the use of these accidental arsenical copper

alloys, which were extensively produced for a very long period over most regions of the ancient world. Primitive man, when he stumbled upon the thin layers of concentrated copper ores immediately below the gossan must soon have appreciated that they produced artefacts having properties vastly superior to those of the copper hitherto obtained from oxide or carbonate ores. On the basis of gradually accumulated experience he would have sought for similar or even richer ores in other localities, but in view of the absence of any concept of alloying it seems unlikely that attempts were made to control the hardness of the copper obtained by adjusting the mixture of ores fed into the smelting furnace (Darling 1990).

We have discussed alloying with arsenic in chapter 3. Here we describe its occurrences and properties:

Arsenic Minerals in India

Raghunandan *et al.* 1981 cite the following sources.

- Himachal Pradesh: Uchich in Kulu.
- Uttar Pradesh: Malari (Chamoli), Askot (Pithoragarh). Traill (1832:17) refers to the digging up of yellow arsenic in two or three places in the old 'Bhotia Mahals of Kumaun', within the Juwar and Darma ghats.
- Rajasthan: Dariba-Rajpura-Bethumni lead-zinc belt, Kolihan sector of Khetri copper mines, Zawar, Jagpura (Banswara), Samodi (Bhilwara).
- Madhya Pradesh: Salaiya in Chhatarpur, also in Bundelkhand.
- Maharashtra: Thaneswara in Chandrapur.
- Karnataka: Chitradurg schist belt, Gonuru-Halli-Chikkanahalli stretch.
- Orissa: Sargipalli lead deposit in Mayurbhanj.
- Sikkim: Darjeeling, Pedong.
- North-eastern region: Buragaon, Barapani-Tyrsad.
- In the glacial moraines of the Western and Central Himalayan region also arsenic minerals are found.

I have suggested that the contacts between the Neolithic Burzahom and the Harappans (as indicated by the presence of the Harappan beads and Kot Diji pottery) may possibly be based on the supply of arsenic ores from the glacial moraines of Kashmir. Of course, this needs to be verified.

Role of arsenic

In answer to my queries Dr Sabine Klein has kindly expressed the following views about the use of arsenic: "Whether arsenic (As) metallurgy started deliberately or not is unknown. Adding As deliberately means to be able to control the smelting conditions in an absolutely perfect manner, and the perfection people reached at this time is not very clear yet. It also depends strongly on the ores available, especially the levels of As reached in the ores.

"A few per cent of As in alloys can easily be reached by smelting copper ores with a certain As content. Lots of As will be lost during smelting, but it is easily possible to obtain low percentages of As without adding As to the charge, if there is some As available in the copper ores.

"Total absence of As in the alloys means definitely absence of As in the ores. If you have As content in the lower percentage range, it could have been a process of smelting arsenic—

containing copper ores; whereas in high percentage ranges, there has almost definitely taken place addition of ores with higher As content such as sulphide ores. For example, Arsenopyrite contributes about 46 wt% As to the charge, Enargite about 19 wt% As. It is still unknown whether co-smelting procedures of copper oxide and arsenic-bearing sulfides were deliberately carried out or not. The boundaries are fluent"! (Klein pers. comm.).

In connection with the study of arsenic, Rapp (1988) says, "Analyses from dozens of early metallurgical centres have shown that arsenic bronzes were fairly common in the Chalcolithic and Early Bronze Age. Coghlan (1972) and others have detailed the important property changes with the addition of varying of alloying arsenic with copper. The use of arsenic was not only widespread, it was intensive. In a fourth millennium BC Near Eastern hoard of copper objects, twenty-four of thirty-six analyzed had an average arsenic content of 5.23% (Muhly 1977).

"Unlike lead there is no evidence that arsenic was ever used as a metal (and native arsenic is very rare) or found as an ingot (such as copper and tin). Thus arsenic must have been alloyed with copper by the smelting of complex ores containing both copper and arsenic. There seems to be a consensus among archaeometallurgists that the first copper minerals smelted were the hydroxycarbonates (malachite and azurite) and the oxides (cuprite and tenorite), yet the first alloys were arsenical. McKerrell and Tylecote (1972) and many others have suggested that the metallic looking complex copper arsenic sulfide mineral tennantite would come from the lower unoxidized zone (along with many metallic-looking copper sulfides).

"The following arsenates are all associated with malachite in the oxidized zone of copper deposits in Europe, the Near East (including Russia), and elsewhere:

Olivenite	$\text{Cu}_2(\text{AsO}_4)(\text{OH})$
Clinoclase	$\text{Cu}_3(\text{AsO}_4)(\text{OH})_3$
Tyrolite	$\text{CaCu}_5(\text{AsO}_4)_2(\text{CO}_3)(\text{OH})_4 \cdot 6\text{H}_2\text{O}$
Mimetite	$\text{Pb}_5(\text{AsO}_4)_3\text{Cl}$
Adamite	$\text{Zn}_2(\text{AsO}_4)(\text{OH})$
Erythrite	$\text{Co}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$
Annabergite	$\text{Ni}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$

"Use of the last four could account for the occasional high Pb, Zn, Co, or Ni contents of arsenic bronzes. And oxide copper ores rich in arsenic would lose less arsenic during smelting than the sulfide ores.

"The beginnings of arsenic and copper alloying may well be coincidental, or nearly so, with the beginning of smelting complex sulfide ores. Although others have suggested the tetraedrite-tennantite series, Cu_3As_4 , as the most likely ore, I believe that enargite is a more likely candidate. Tetraedrite is much more common than tennantite, and early arsenical coppers usually do not have high concentrations of antimony. Enargite is often found in large quantities and is well known from deposits in Austria, Hungary, and at large deposits at Bor, Yugoslavia. All these copper ore minerals oxidize to malachite.

"Although there are arsenical tin deposits at Cornwall, in Bolivia, and elsewhere, there is little evidence to indicate the early importance of this type of deposit. Interest in the mineral stannite ($\text{Cu}_2\text{FeSnS}_4$) may be revived with the recent discovery by Yener (1985) of stannite deposits near early metallurgical sites in southern Turkey" (Rapp 1988).

Moorey (1994: 252) also thinks that "The recognition of the role of arsenical coppers in the early history of metallurgy has modified views about the first emergence of copper-tin alloy

in the Near East, as elsewhere. The distinction between copper and bronze is first made in the 'archaic' texts from Ur (Early Dynastic I) (Burrows 1935: no. 373) at the time of the earliest archaeologically attested tin-bronze objects in Mesopotamia. Wertime (1980) and Charles (1978; 1980) have both associated the exploitation of arsenical ores of copper and the subsequent introduction of tin ores by calling attention to the polymetallic character of many ore-bodies and to the community of colour between some tin ores and arsenical copper ores. The tin ore stannite, for example, resembles in appearance the copper-arsenical mineral enargite, so anyone used to enriching copper with enargite would be happy to use stannite for the same purpose. Both scholars have suggested that another context in which miners might inadvertently have come into contact with tin is offered by the stannic ferrous gossans that may cap sulphide ore bodies, especially if such gossans were used as fluxes in copper smelting." Copper alloying in India has been discussed in chapter 3.

With this chapter we come to the end of our survey of archaeometallurgy. In the next and final chapter we will give our conclusions.

CHAPTER 14

CONCLUSIONS

We now come to the end of this exploration of early metallurgy and archaeology in South Asia. In this survey, we have tried to situate metallurgy in the matrix of archaeology and socio-economic evolution. We have tried to use an interdisciplinary approach to understand the evidence of metals in South Asian protohistoric cultures. We have also highlighted the possible role of the Central Himalayas as they have been considered only as *culs-de-sac* outside the pale of the socio-economic dynamics of northern India. We have also described the South-east Asian scene as we feel that it also has a relationship with India, through the Himalayan corridors. West Asian relations with South Asia, perhaps have been over-emphasised and a lot of literature exists on these contacts. We have therefore discussed the West Asian evidence mainly in the context of the origins of copper and iron metallurgy. We have emphasised on South-east Asian and Chinese contacts as they need to be explored further.

We began by introducing the importance of material remains to reconstruct the past (chapter 1). We gave examples from some important recent writings, especially on the Indus related artefacts.

In chapter 2 we presented the ancient mining evidence from South Asia in a pan-Asian perspective. We tried to bring out, on the basis of the recent research, the still to be resolved controversies regarding ore-artefact correlations. A combination of comparison of trace impurity analysis and lead isotope ratio seems to work better but the geochemistry of ore bodies has to be thoroughly investigated before trying such correlations. Young and Pollard (1997) have described a variety of new techniques that have recently been developed and are being increasingly used in archaeometry. In fact, Suzanne and Young *et al.* organised an exciting symposium on *Metals in Antiquity* at Harvard University in 1998 (Young *et al.* 1999). We briefly indicated the types of presentation made in this symposium on archaeometallurgy in chapter 3.

Below we summarise the main conclusions and point to the problems and lacunae to be addressed to.

Unfortunately in India, very little work has been done on ore-artefact correlation (Agrawal 1971; Hedge 1965). Sharada Srinivasan (1999), a promising young scholar, has used some of the techniques to study south Indian metallurgy. In this field, considerable work remains to be done to identify the ore bodies used by the Harappans, the Copper Hoard culture and also the Chalcolithic cultures. We understand that an ambitious project is on the anvil to be led by R.S. Bisht, J.S. Kharakwal and Srinivasan.

We also pointed out that in view of the large copper mineral deposits in Rajasthan and the importance of the Ganeshwar culture as the manufacturing agency for both the Harappans and the Banasians, the import of copper from Oman appears to be ruled out. Moreover, Meluhha

has been identified with the Indus region, which was the traditional supplier of copper to West Asia. But we must admit that at the moment it is only circumstantial evidence. Definitive ore-artefact correlations need to be worked out on the basis of hard evidence provided by chemical and isotopic analysis.

Making and use of metal artefact was a big revolution from the Stone Age. Metals alone made the civilisation possible. To extract metal from minerals and to make artefacts out of metal require a variety of techniques. We have discussed this in chapter 3. The Indus tradition seems to have most advanced casting and alloying technologies. There is evidence of deliberate alloying in their tradition. The Chalcolithic cultures used mostly unalloyed copper or a limited amount of tin alloying. On the other hand, half of the Copper Hoard objects analysed by us showed arsenic alloying. It appears to us an artefact of the use of arsenical copper ores, as are found in the Central Himalayas. We have also indicated that on the basis of the alloying pattern itself, one can conclude that the technological traditions of the Harappa, the Copper Hoards and the Chalcolithic cultures, there was hardly any interaction.

A great deal of work needs to be done on smelting processes, nature of alloying and mining technology used by these protohistoric cultures.

Even a decade back, the Harappa culture appeared to be a sudden phenomenon without any antecedents. The work of the French team lead by Jarrige has now proved beyond doubt that the Indus civilisation (Harappa culture) was in fact a culmination of a long process beginning with the Mesolithic and passing through the Neolithic stage. Copper makes its appearance in late Neolithic levels in Baluchistan and Afghanistan. We have traced the development of pre-Harappan cultures in Chapter 4 though there is very little metal in these cultures. In chapter 4 therefore the emphasis was not on metallurgy but on delineating the developmental processes which culminated in the Harappa culture. chapter 4 therefore sets the stage for understanding the genesis of Harappa culture. Thanks to the efforts of the French team we have considerable archaeological evidence to unravel this process of transition from the Neolithic to the Urban stages. Still, very little work has been published on the beginnings of metallurgy in this region. This is an important task and needs to be addressed urgently.

We discussed the metallurgy of the Harappans in chapter 5. Thanks to the publications of Kenoyer, Meadow, Heather Miller, Vidale and others, we have considerable data on the Indus crafts and their socio-economic aspects. Heather Miller has done an excellent job of studying the pyrotechnology of clay artefacts. But even here, there is not much new work on the metallurgy of the Harappans, which has been published. The Ganeshwar complex of Rajasthan is crying for attention. About 5,000 copper artefacts have been found in this area and it appears that they were manufacturing metal artefacts for the Harappans as well as for the others. As we have discussed in chapters 5 and 6, Ganeshwar complex was in close vicinity of the big Harappan sites of Rakhigarhi and Kalibangan. As we explained in chapter 5, the major Harappan towns probably represent the linguistic divisions. Harappa is in the Punjabi speaking area; Mohenjodaro in Sindhi language area; Dholavira in Gujarati speaking region; and Rakhigarhi in Rajasthani language area. We have also discussed the regional variations despite the overall uniformity of the Harappan traits. But overriding these linguistic and cultural criteria, these Harappan towns had an economic basis too. Harappa was controlling the trade through the northwestern passes as also the mineral and timber trade from its mountainous hinterland. Mohenjodaro seems to be controlling the maritime trade. The only explanation for the large town of Rakhigarhi could be the control of copper minerals in its hinterland.

The circumstantial evidence of the Ganeshwar complex producing a huge amount of copper artefacts, the location of Rakhigarhi, the rich copper mineral belt of Khetri in Rajasthan and the references to Meluhha, in the Mesopotamian texts, of a supplier of copper, all indicate that the main source of the Harappan copper must be Rajasthan. This therefore rules out any significant imports of copper from Oman. But this circumstantial evidence needs to be substantiated by analytical work.

The Copper Hoard culture continues to be an enigma as no definite archaeological assemblages have been associated with it. Nor do we have any definite dates for this culture. We had analysed 47 Copper Hoard artefacts out of which almost half showed significant arsenic alloying. We suspect that it was not a deliberate alloying but perhaps the copper mineral used was rich in arsenic. We have argued for the possibility of use of Central Himalayan copper minerals, which are rich in arsenic, as the source of Copper Hoard metal (chapter 6). The Copper Hoards are more of an archaeological challenge, as we have to find some definite archaeological remains that belong to them. Only after that a detailed metallurgical study will have some meaning.

The Chalcolithic cultures (Banas, Kayatha, Malwa, and Jorwe) appear to have a Neolithic type of economy though some copper is available with them. For the Banasians the probability of use of Rajasthan minerals is high but from where other cultures were obtaining their copper is not at all clear. The Kayathans seemed to show a developed craftsmanship in casting, as exemplified by their celts. We have indicated that the black cotton soil was a handicap for the Chalcolithic cultures to usher into urbanisation. With their meagre copper, they could only colonise the narrow alluvial strips, which could not generate adequate agricultural surplus to usher in urbanisation. It is important to know that the Chalcolithic copper technology is mainly based on unalloyed copper as only a limited amount of tin alloying is in evidence (chapter 7).

As we have pointed out, that the alloying pattern itself seems to indicate that the three metallurgical traditions (Copper Hoard, Harappan, Chalcolithic) do not seem to have much interaction among themselves though they were part contemporary. A comparative study of these three technological traditions needs to be made.

In chapter 8 we have emphasised the role of the Central Himalayas in both copper and iron technologies of north India. Due to geographical isolation, these areas are often ignored in the study of north Indian metallurgy. This area requires much more exhaustive studies than have been carried out so far.

This problem is discussed further in a Southeast Asian perspective in chapter 9. We have indicated the possibility of early copper technology reaching the Central Himalayas from Southeast Asia through the Mon Khmer speaking people coming through the Himalayan corridors. In this light, the Copper Hoard culture may have a Southeast Asian inspiration. But at the moment such possibilities are more in the realm of speculation and need to be further explored with more metallurgical, archaeological and linguistic data.

Chapter 10 is basically a brief account of Chinese and Japanese archaeometallurgy. The Chinese metallurgy presents a stark contrast with the Indus tradition. The monumentality of their statues and ritual vessels presents a big contrast with the functional and non-elitist artefacts of the Harappans. But as recent evidence has shown (Yasuda, 1999), the very early beginnings of agriculture in Southeast China at 14,000 BP and of ceramic technology a little later, seem to make it possible that early agricultural and ceramic technologies could have travelled to Brahmaputra valley and then to the Central Himalayas. These new discoveries need to be studied in the light of both archaeological and linguistic evidence. These problems have been discussed

in chapters 9 and 10. The Indian Northeast continues to be *terra incognita* and even the Central Himalayas are hardly explored. These areas provide both potentialities and challenges for new perspectives to emerge.

The main focus of this book is on the Bronze Age but chapter 11 covers the early iron technology and its role in the urbanisation of the Ganga Valley in mid-first millennium BC. Recent work provides only a bare outline of these processes. It has to be done on a larger and multidisciplinary scale. It appears that some Indo-Japanese collaboration may address this problem in the near future under the Environment and Civilisation Global Program.

Chapter 12 addresses itself to the history of brass and zinc and explains the enigmatic presence of brass in III millennium BC context in China. It also discusses the earliest zinc distillation technology of Rajasthan.

Chapter 13 deals with the major alloying elements of arsenic, lead and tin. We have very limited data on alloying. Further studies on alloying techniques, as also extraction of alloying metals need to be taken up. We have suggested that the Neolithic Kashmir may have provided arsenical minerals found in the glacial moraines. Kumaun does provide copper minerals rich in arsenic. The sources of tin in antiquity still continue to be controversial topics. The issues of alloying and obtaining alloying minerals require extensive sampling and analysis. We hope that the projects planned by Bisht and Srinivasan will address this problem also.

Thus this book is an attempt to present a synthesis of a variety of evidence – both metallurgical and archaeological – to understand the role of ancient metals in the cultural processes of protohistoric South Asia. We hope that the book also indicates the great potential of such studies in understanding the socio-economic processes during the third and first millennia BC. The book also brings to focus the poor state of research in this field. There are large lacunae in our knowledge. We do hope that this book will inspire further research into these areas, which are so intimately related to archaeology.

I have always tried to use a holistic approach in delineating the human past, though my different books had emphasis on different types of evidence. The Archaeology of India (1982) mainly dealt with archaeological evidence; Man & Environment in India through Ages (1992) had emphasis on palaeoenvironmental data; the present book however deals mainly with archaeometallurgical evidence.

We began this book with a quotation of Cyril Smith and would end it too with his wise words. "Historians and scientists have some important traits in common: they both depend on the critical evaluation of whatever evidence is at hand or can be made available and they both tend to select not the most important aspects of the world (which are beyond intellectual reach) but those that interest them personally and that at any given time appear to be ready to yield new understanding. The material artefacts and the written sources on which the history of technology must be based have not been much argued over, for the interests of both patron and scholar have caused their neglect in favour of the more intellectual side of human development...."

Emphasising the need of using a holistic view, Smith says, "All aspects of human capability are involved in complicated interaction within our changing society. One cannot cleanly separate art from technology or either from science. Though specialisation is both essential and rewarding to individuals and to society alike it is viably so only in a large pattern of holistic interaction...

"If materials science and engineering, though but a small part of the whole human enterprise... be able to make a contribution to the understanding of the changing social and physical world

within which we live, then perhaps a new and more valid alchemy may rise from the same starting point as the old, namely the desire to place in universal perspective what men working intimately with materials know, feel and understand.... Metallurgy is a fully human experience...." (Smith 1977: 39).

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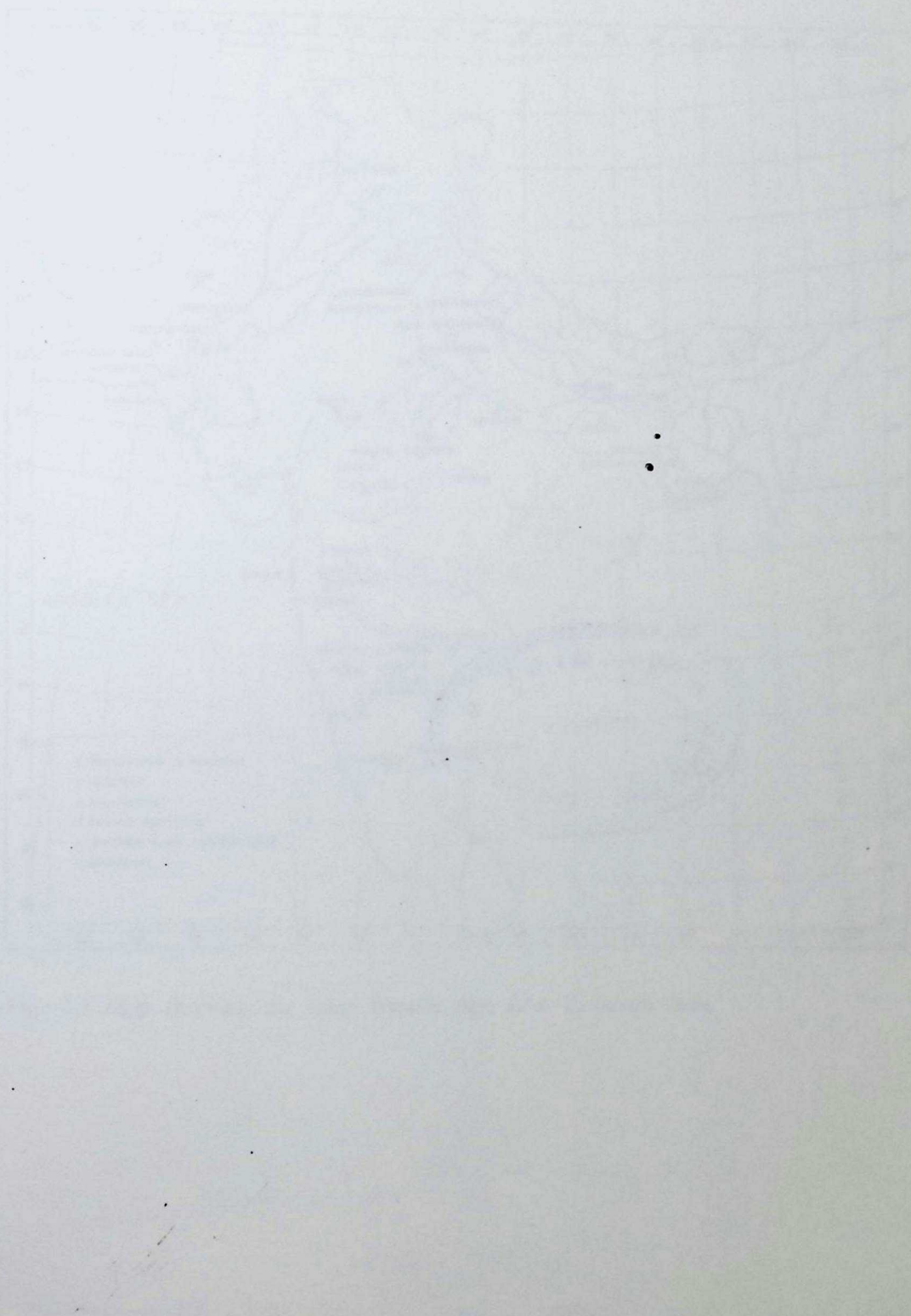
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A bar chart comparing the percentage of artefacts alloyed with various elements across three cultures. The Y-axis represents the percentage of artefacts, ranging from 0 to 50. The X-axis lists the elements alloyed with: Sn, As, Pb, Sn+As, Sn+Pb, and As+Pb. The legend indicates three cultures: Harappa Culture (white bars), Chalcolithic Culture (hatched bars), and Copper Hoard Culture (solid black bars).

Alloyed With	Harappa Culture (%)	Chalcolithic Culture (%)	Copper Hoard Culture (%)
Sn	23	15	0
As	11	0	45
Pb	7	20	2
Sn+As	3	0	0
Sn+Pb	2	18	0
As+Pb	0	0	4

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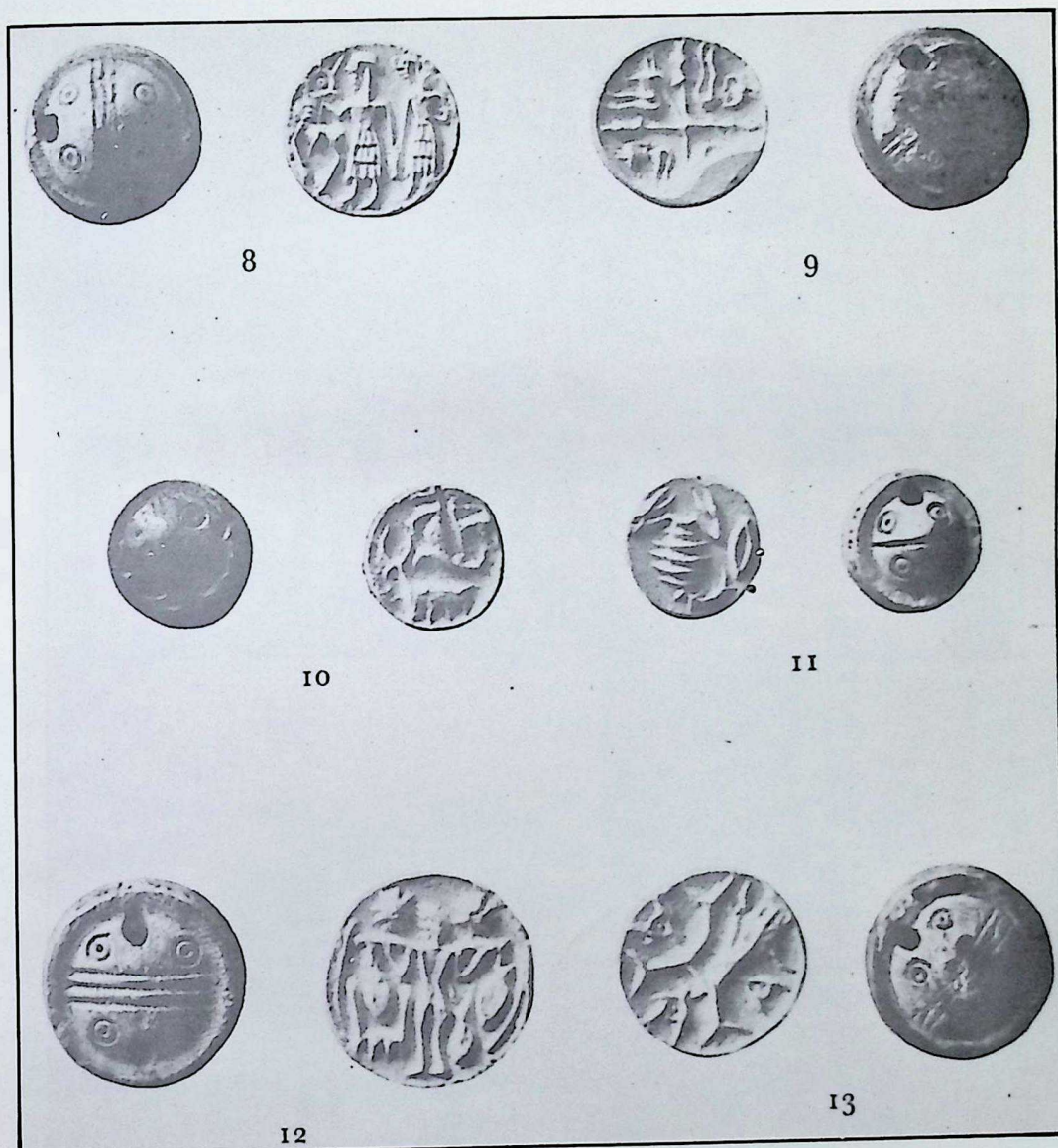


Fig. 5.1 West Asian seals. Similar seal has been found from Lothal (see Lal 1997: Plate 39B).

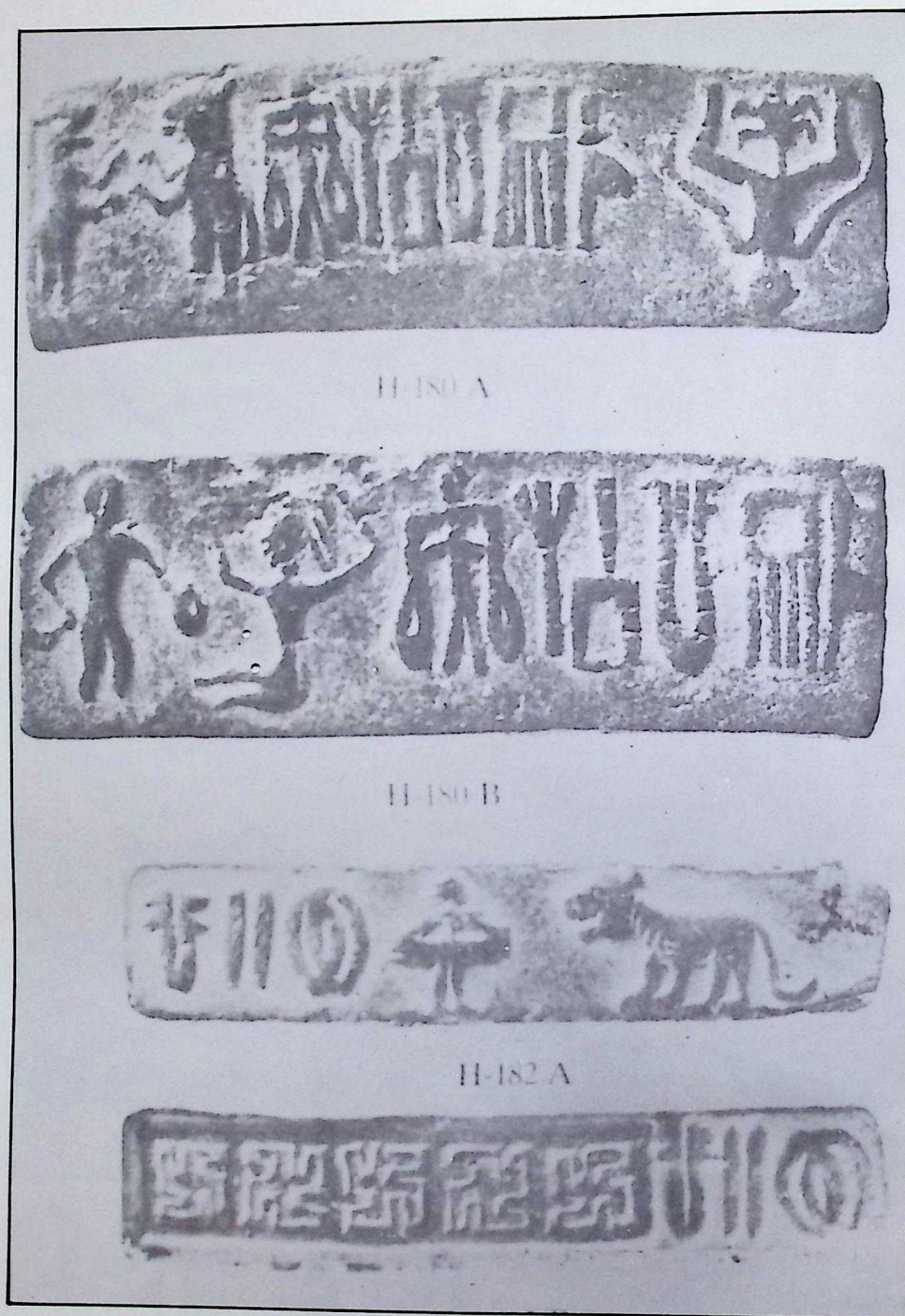


Fig. 5.2 Harappan seal impressions. The top row shows a plant coming out of the vagina of a goddess?

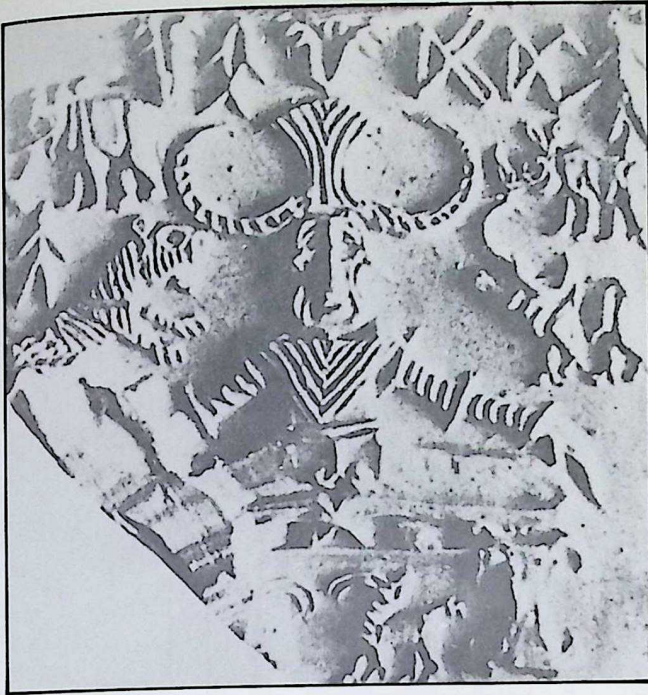


Fig. 5.3 The famous Pasupati seal from Mohenjodaro showing a male deity, with the attributes of the Hindu god Siva.

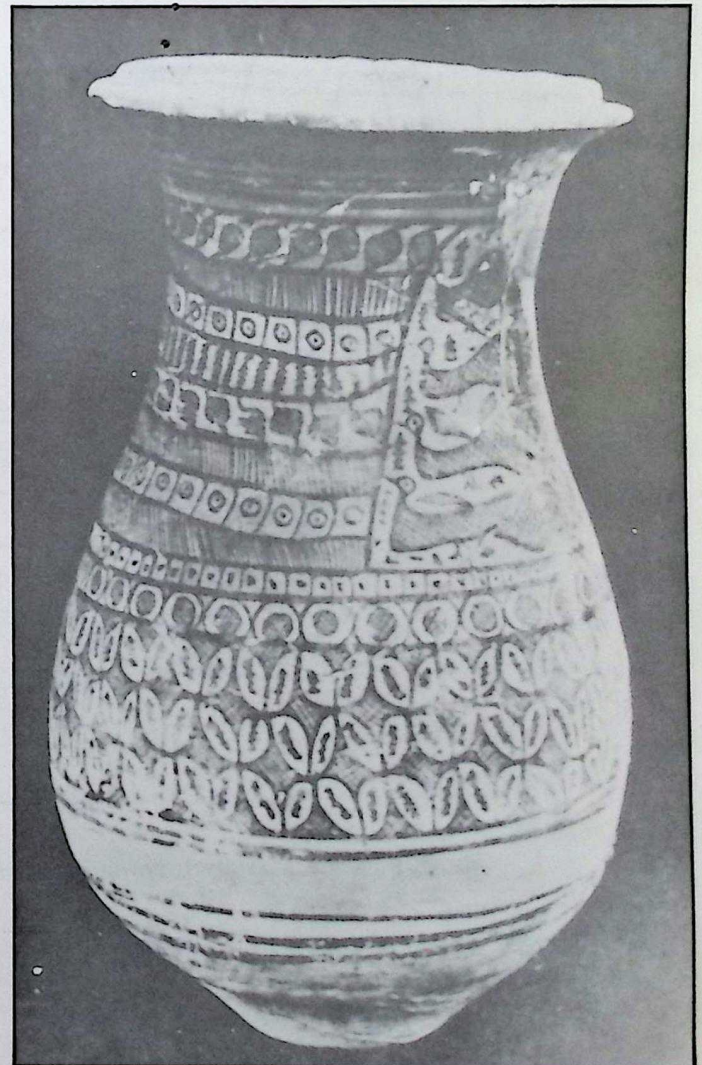


Fig. 5.4 Pottery jar showing typical Harappan motifs like intersecting circles, pipal leaf, peacock etc. Mohenjodaro.

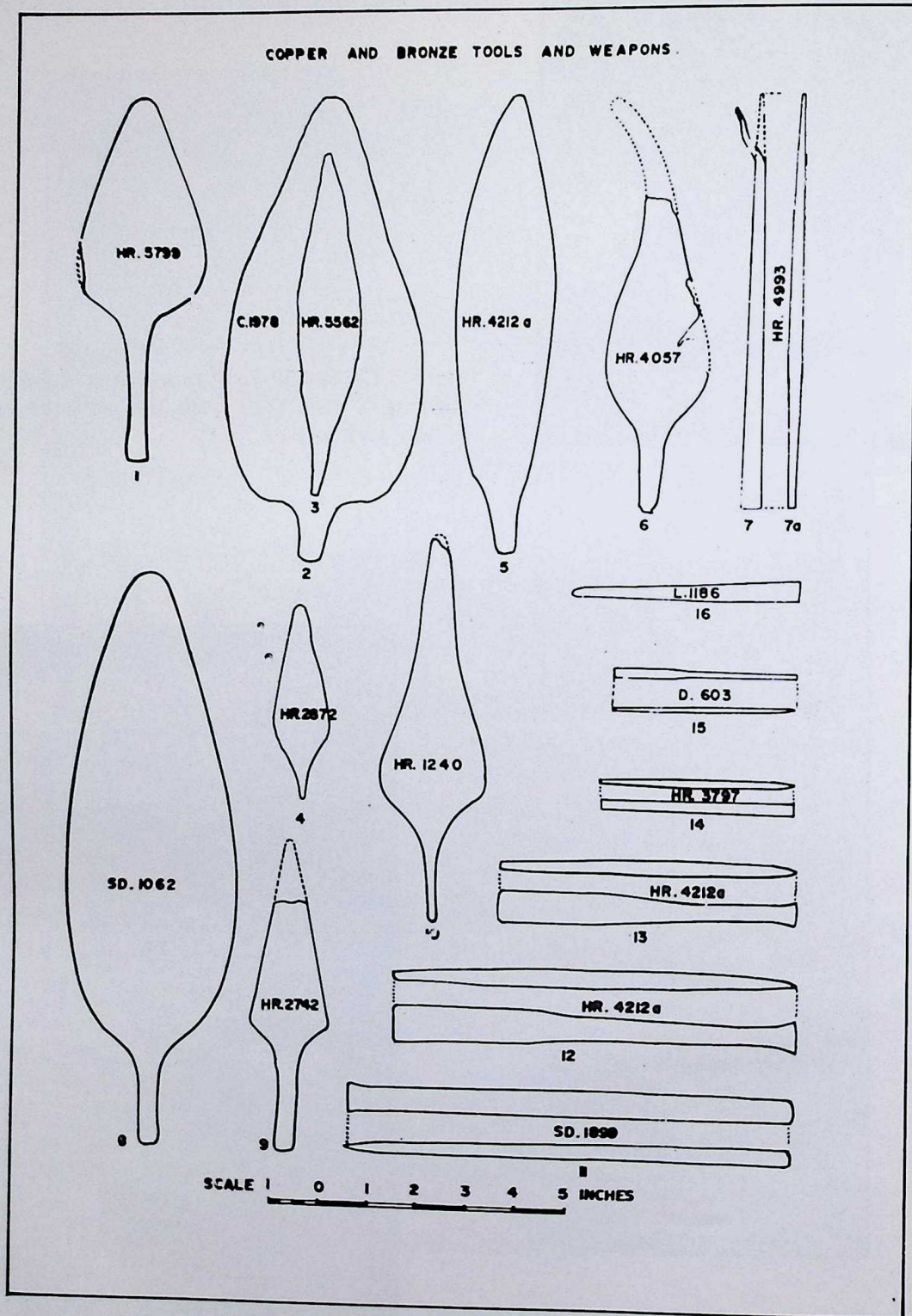


Fig. 5.5 Copper artefact types from Harappa.

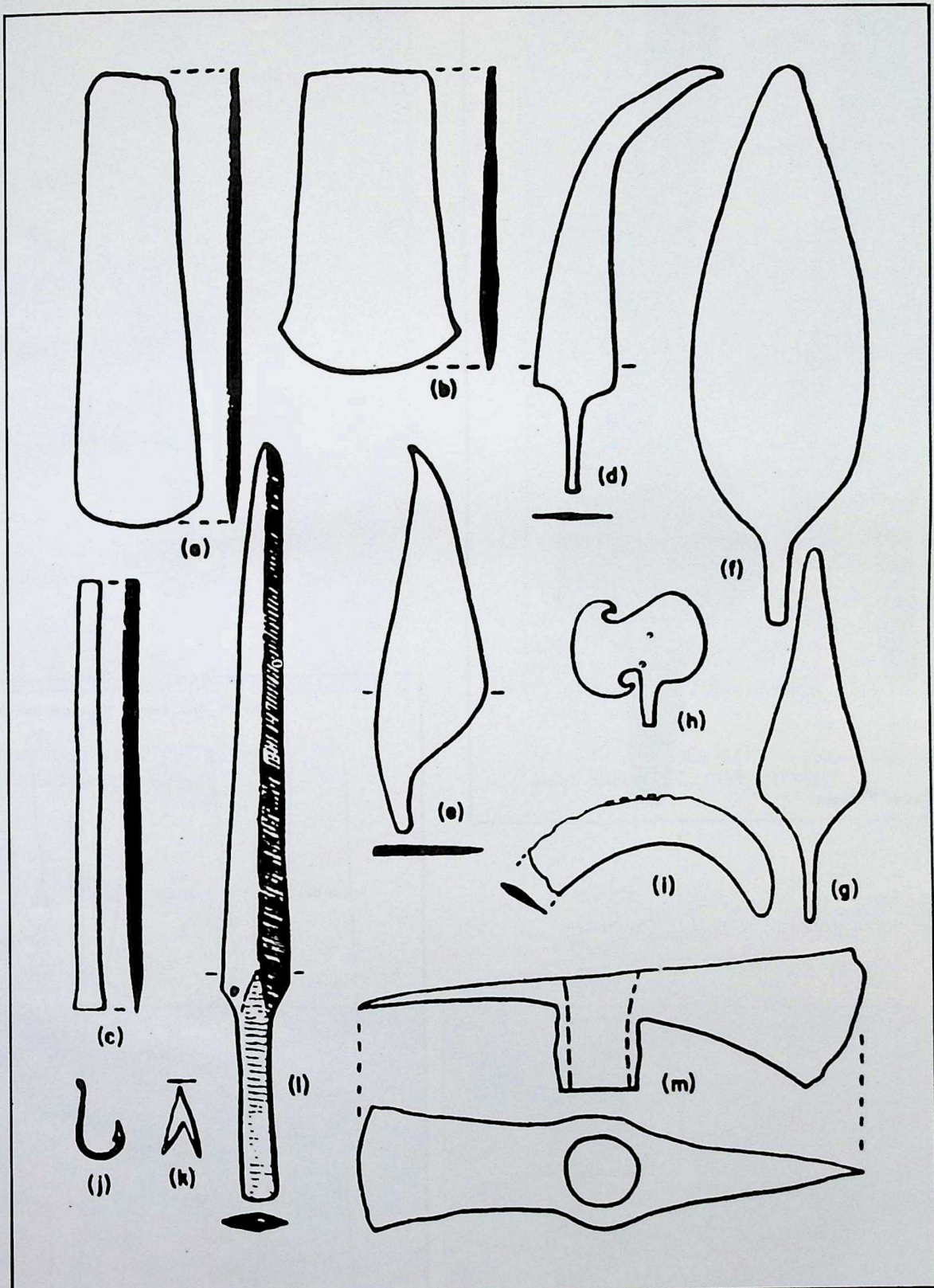


Fig. 5.6 Typical Harappan tool repertoire.

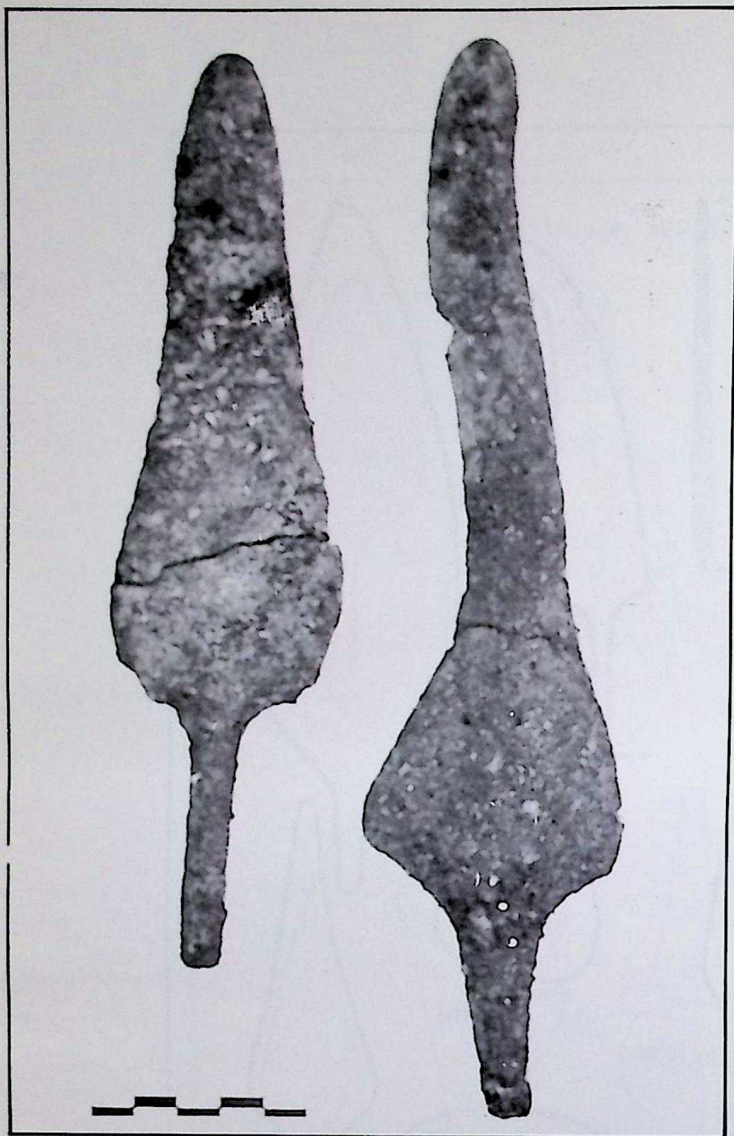


Fig. 5.7 Spearhead and splayed blade from Harappa-1995 excavations.

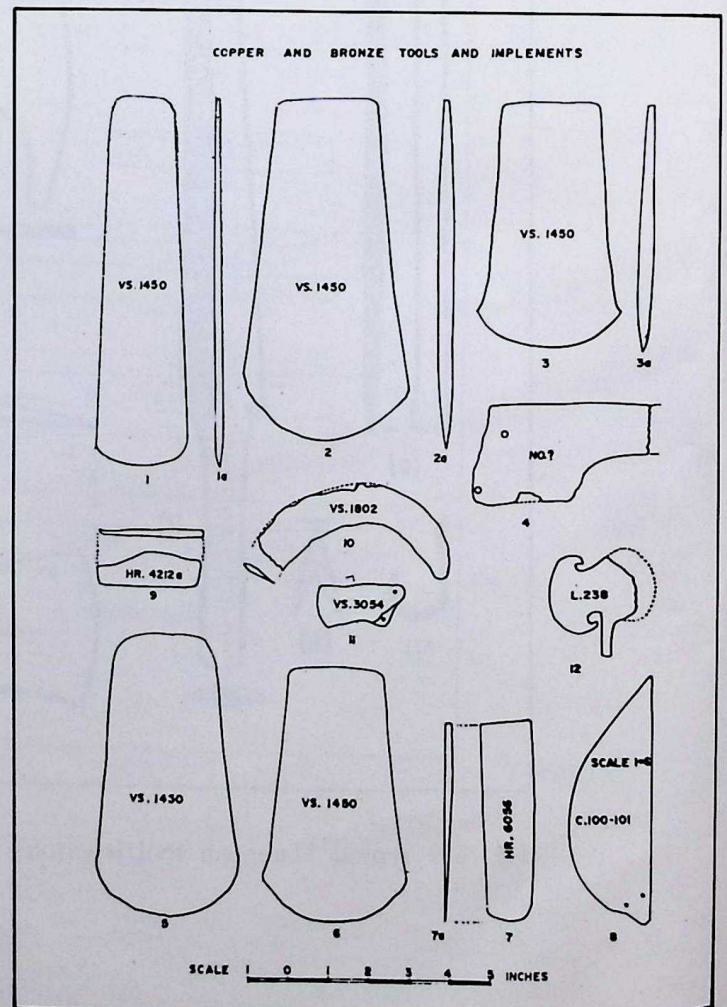


Fig. 5.8 Copper artefact types from Harappa.

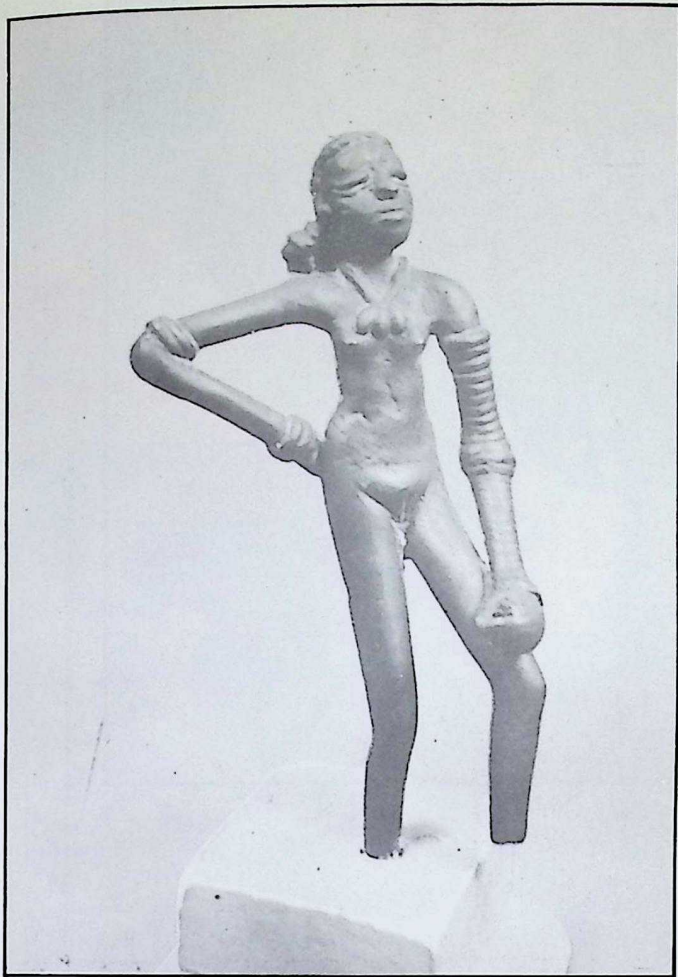


Fig. 5.9 The famous dancing girl in bronze.
Now in National Museum, Delhi.

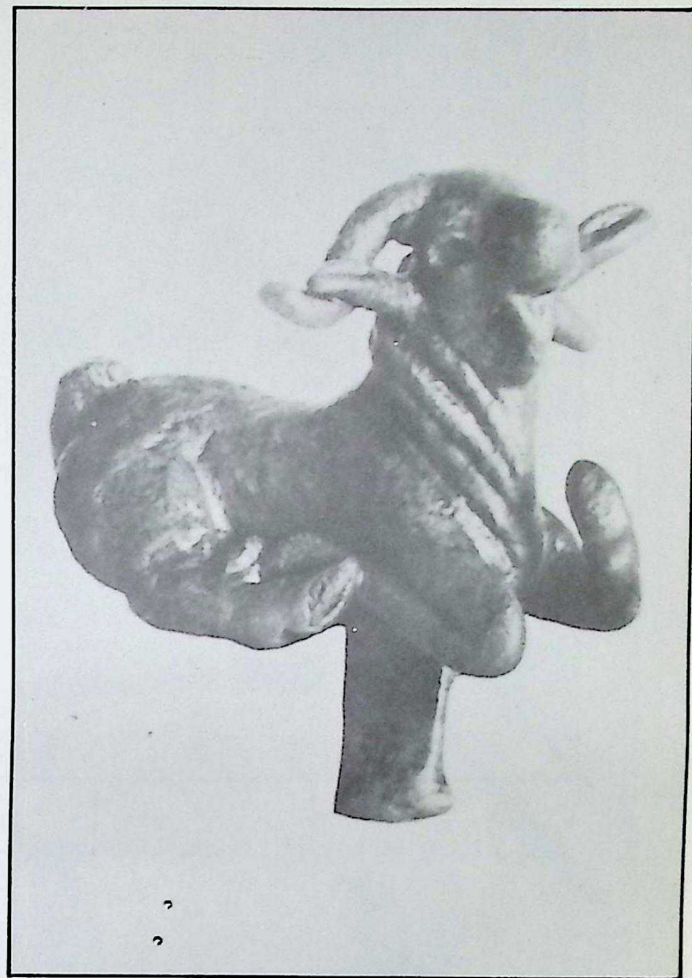


Fig. 5.10 A bronze ram on stand, DK area,
Mohenjodaro. No. DK 10781.

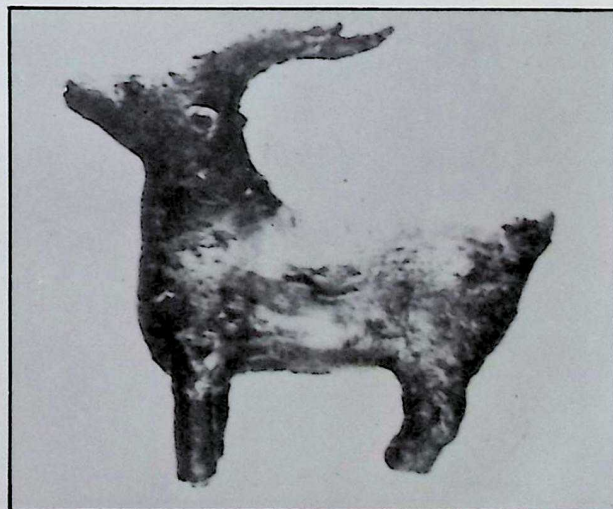
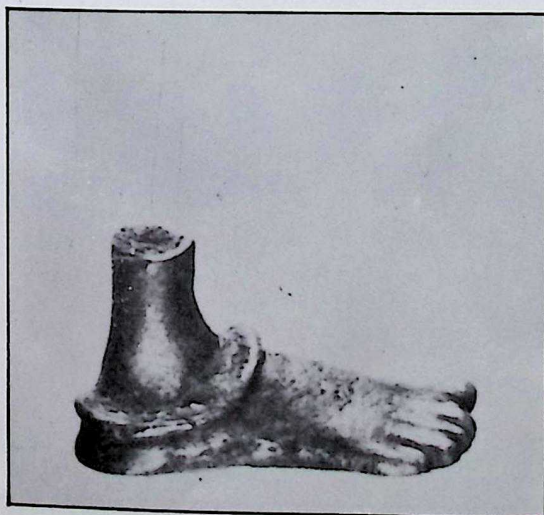


Fig. 5.11 A human foot and a deer from Mohenjodaro.

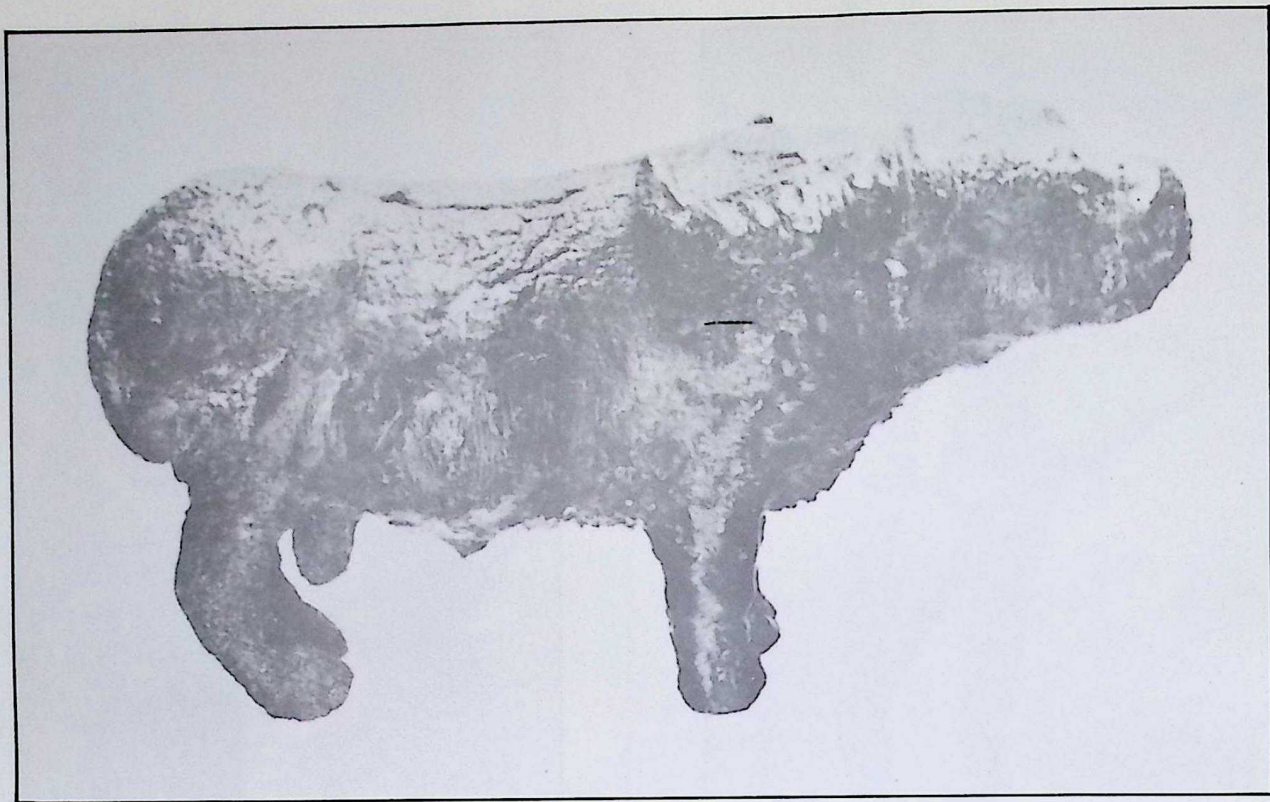


Fig. 5.12 A buffalo in bronze, Mohenjodaro. No. Sd. 3319.

?

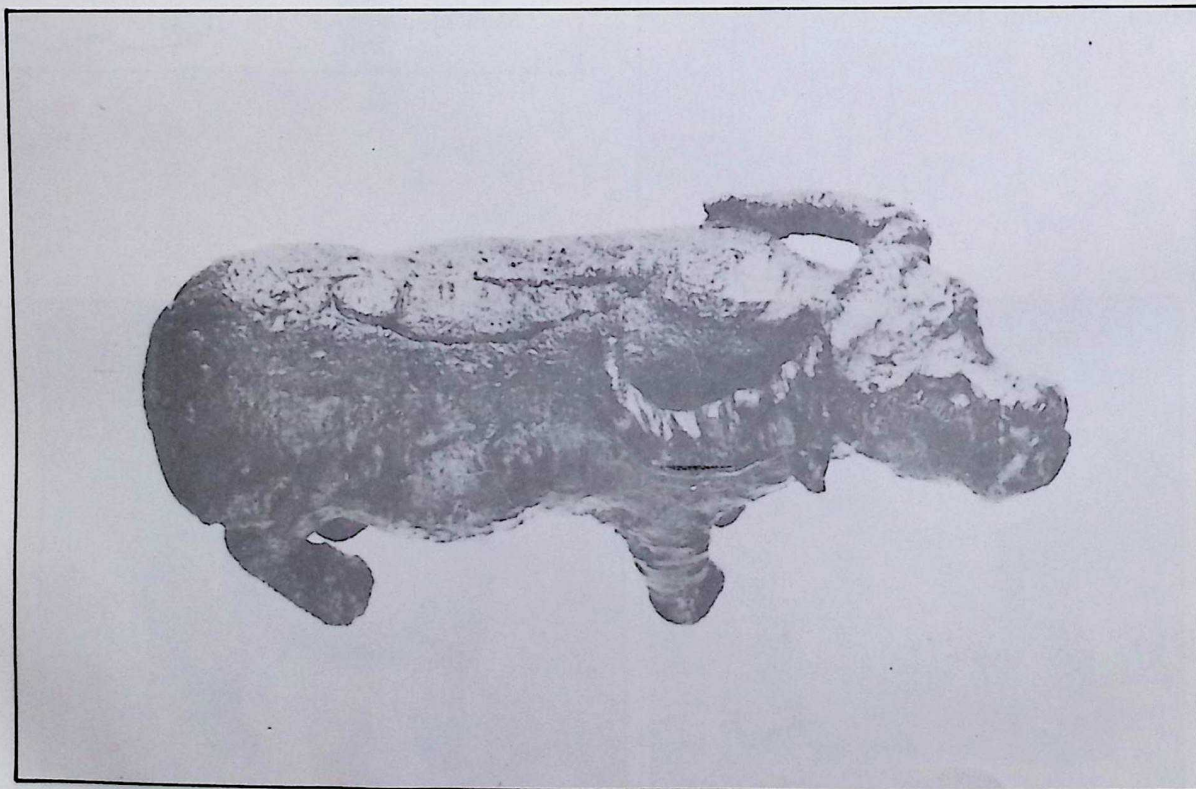


Fig. 5.13 Same bronze buffalo as in Fig. 5.12. Top view.

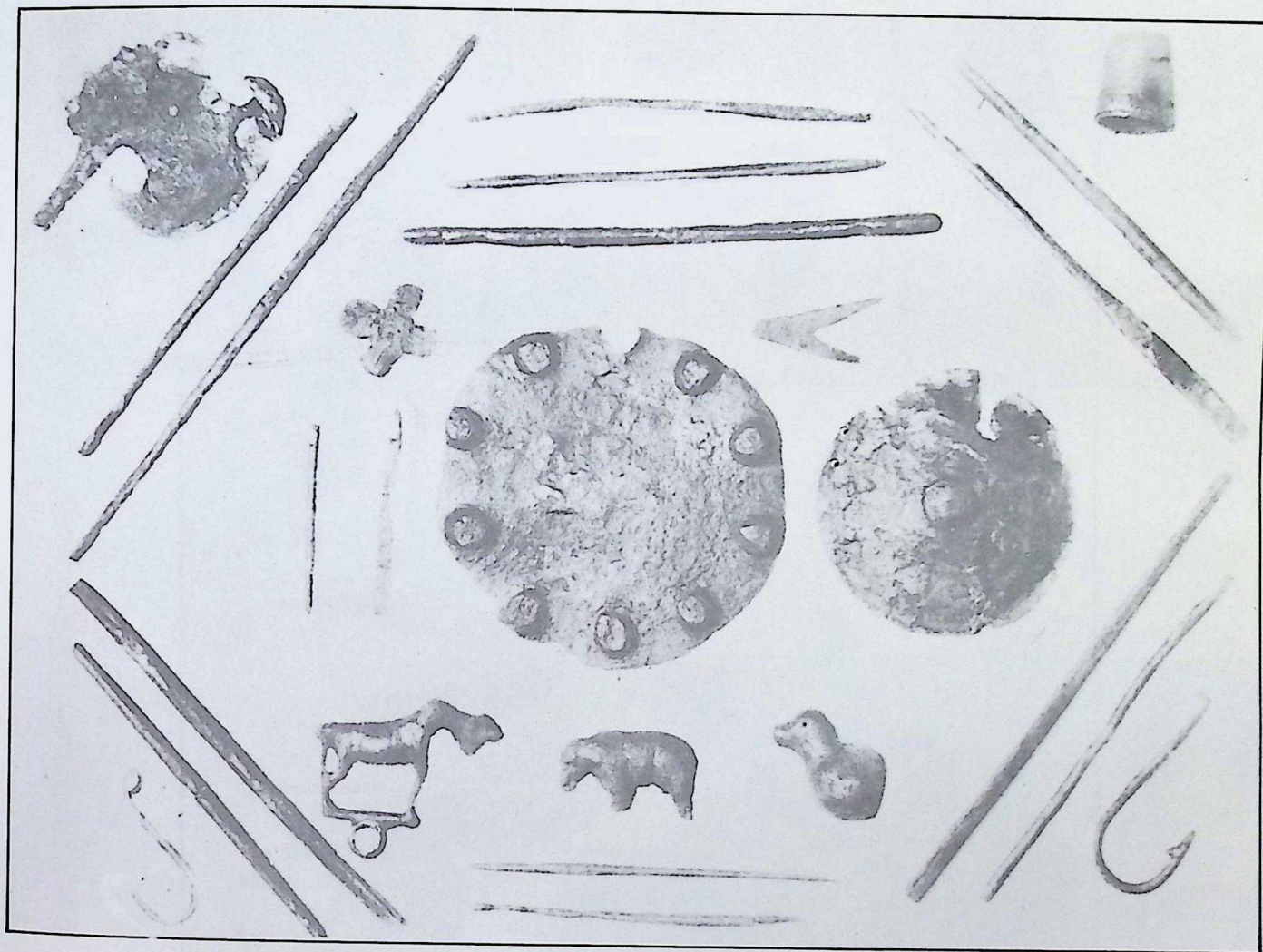


Fig. 5.14 Miscellaneous artefacts from Mohenjodaro.

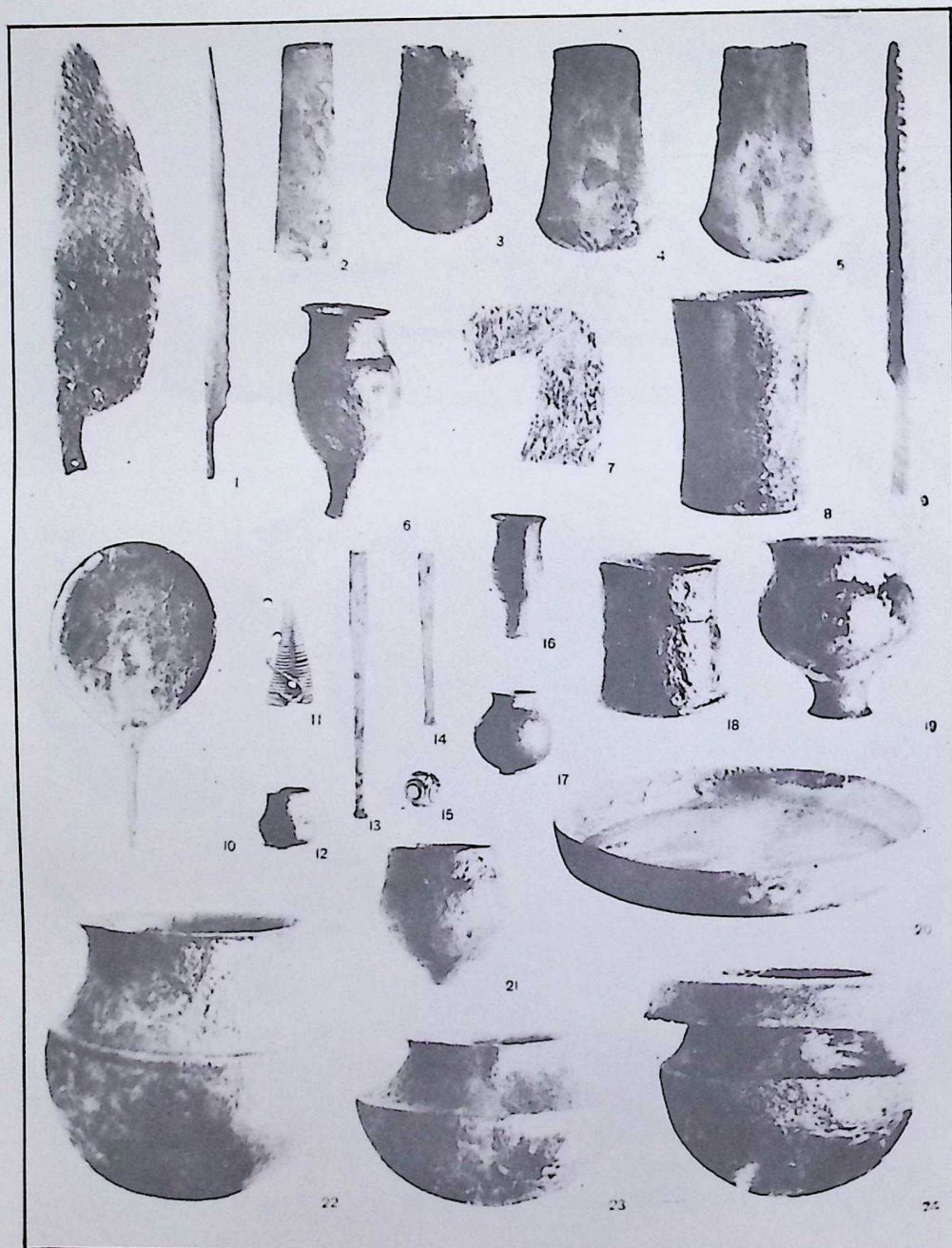


Fig. 5.15 Bronze vessels and other artefacts from Mohenjodaro.

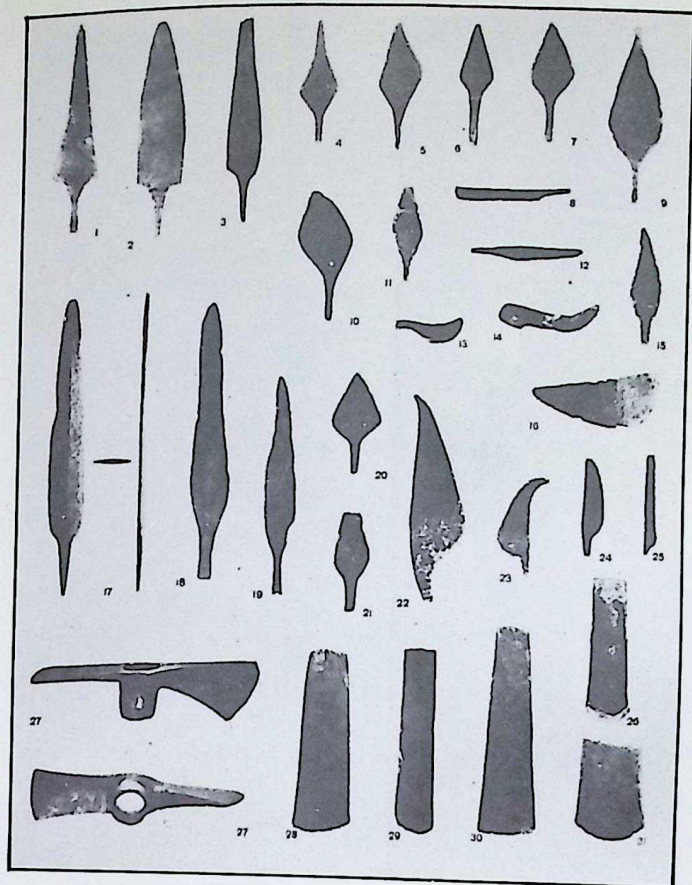


Fig. 5.16 Spearheads, blade-axes, and shaft-holed axe, Mohenjodaro.

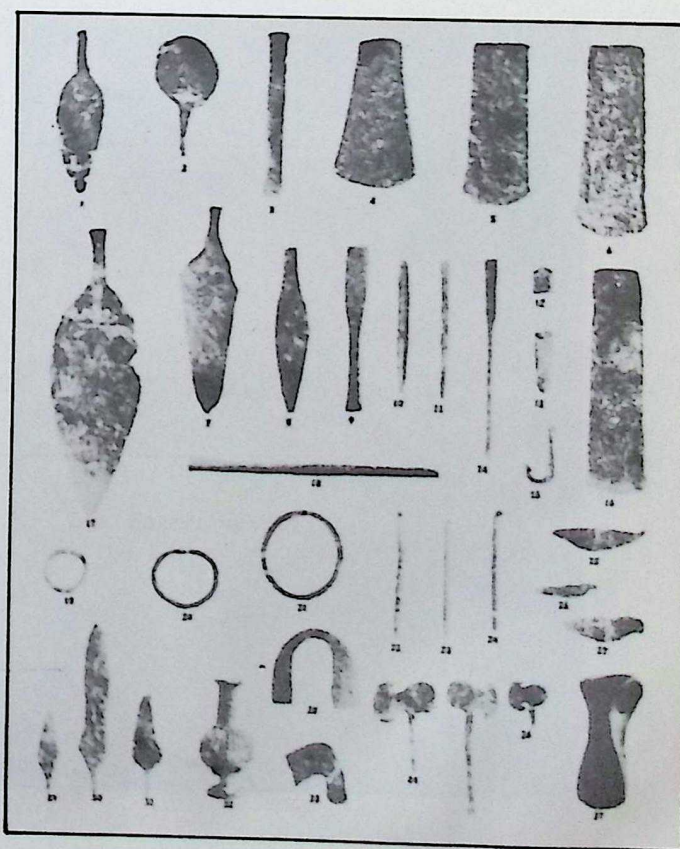


Fig. 5.17 Miscellaneous artefacts from Chanhudaro. Note the socketed axe, 37.

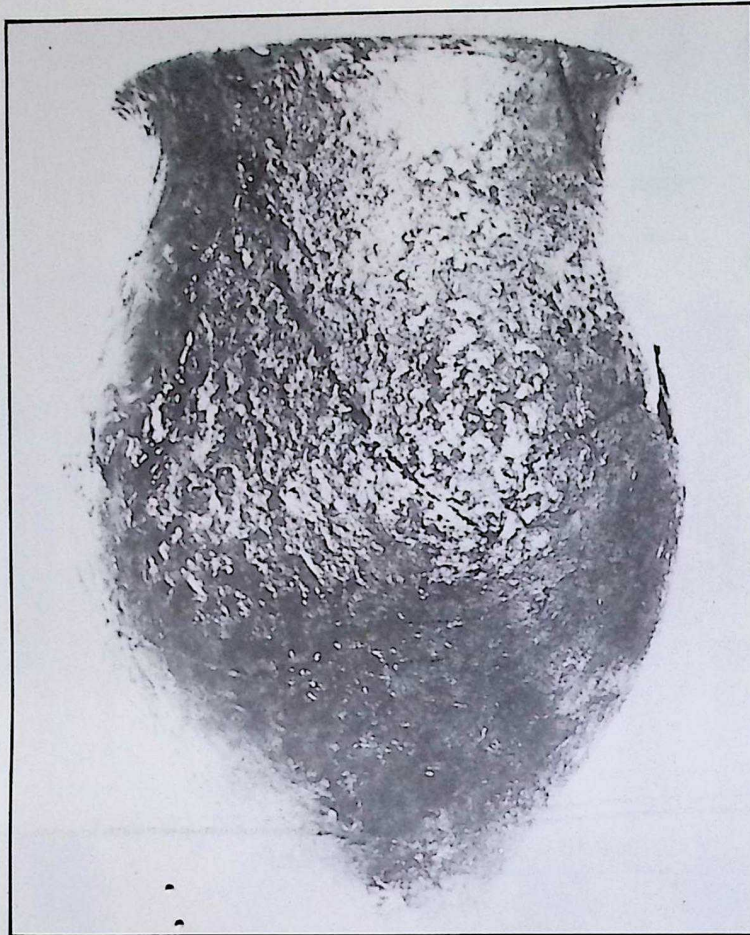


Fig. 5.18 Bronze jar from Mohenjodaro.

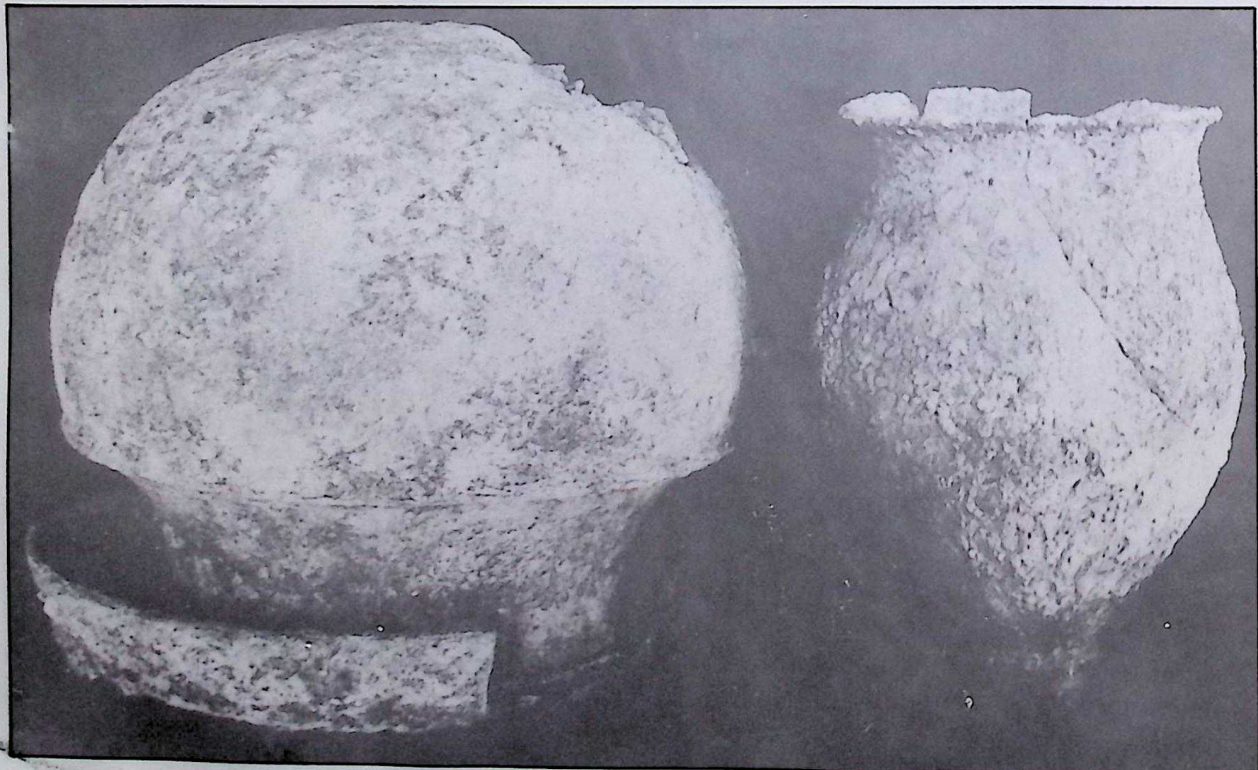


Fig. 5.19 Bronze jar with a lid from Mohenjodaro. It had yielded jewellery.
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Fig. 5.20 Bronze jar from Mohenjodaro.



Fig. 5.21 Copper razor wrapped with cloth from Mohenjodaro.

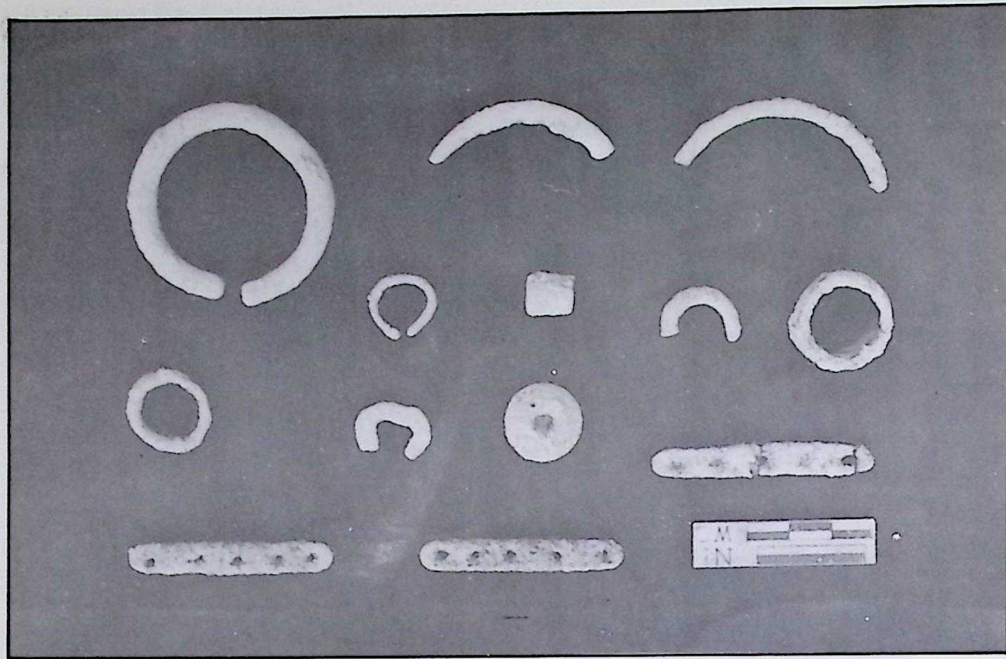


Fig. 5.22 Copper ornaments from Dholavira, Harappan site, Gujarat.

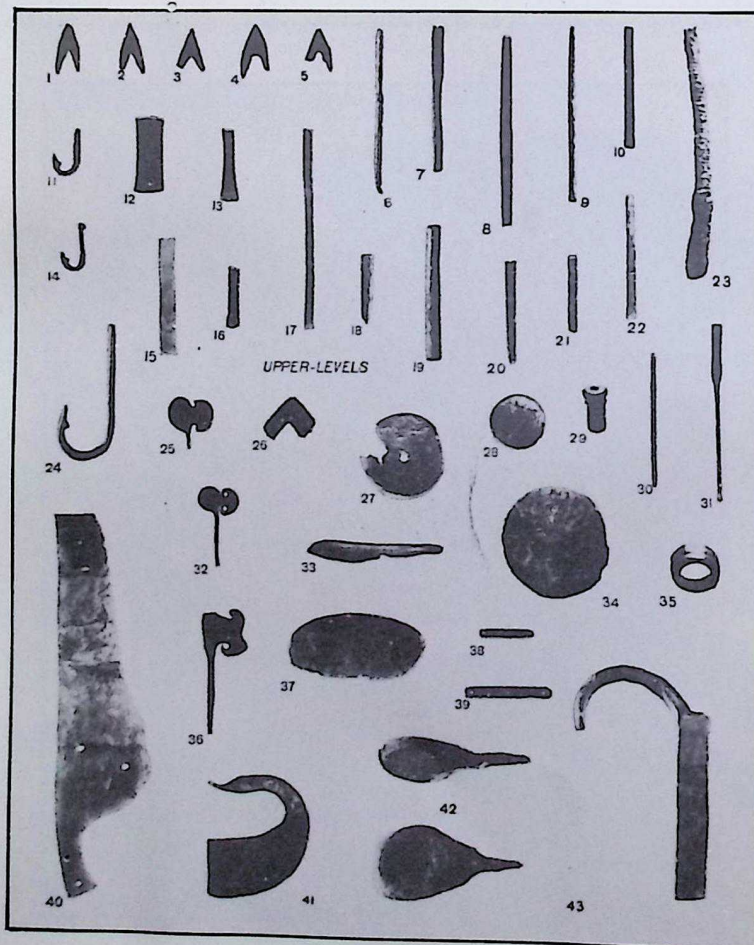


Fig. 5.23 Copper objects from DK area, Mohenjodaro.

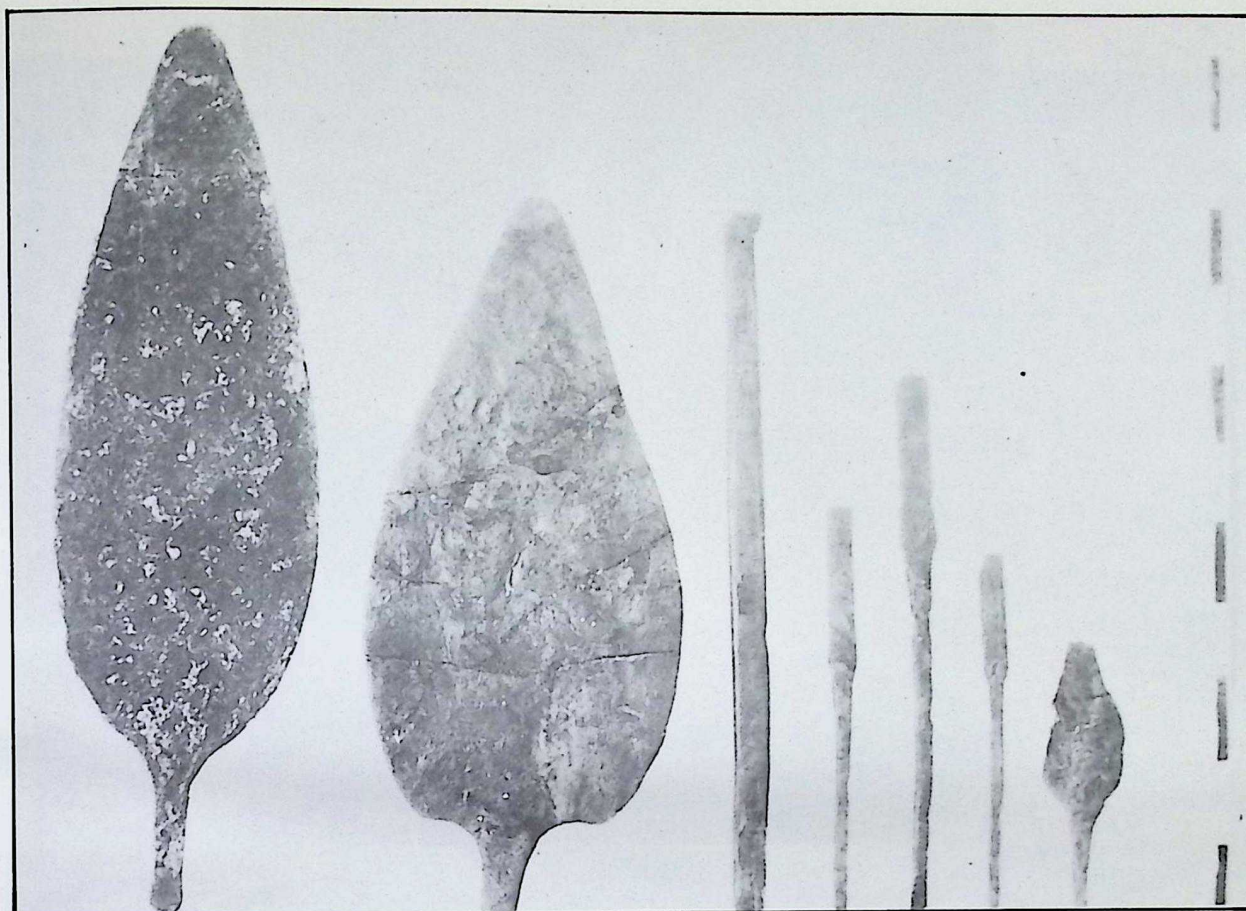


Fig. 5.24 Spearheads and chisels from Mohenjodaro.

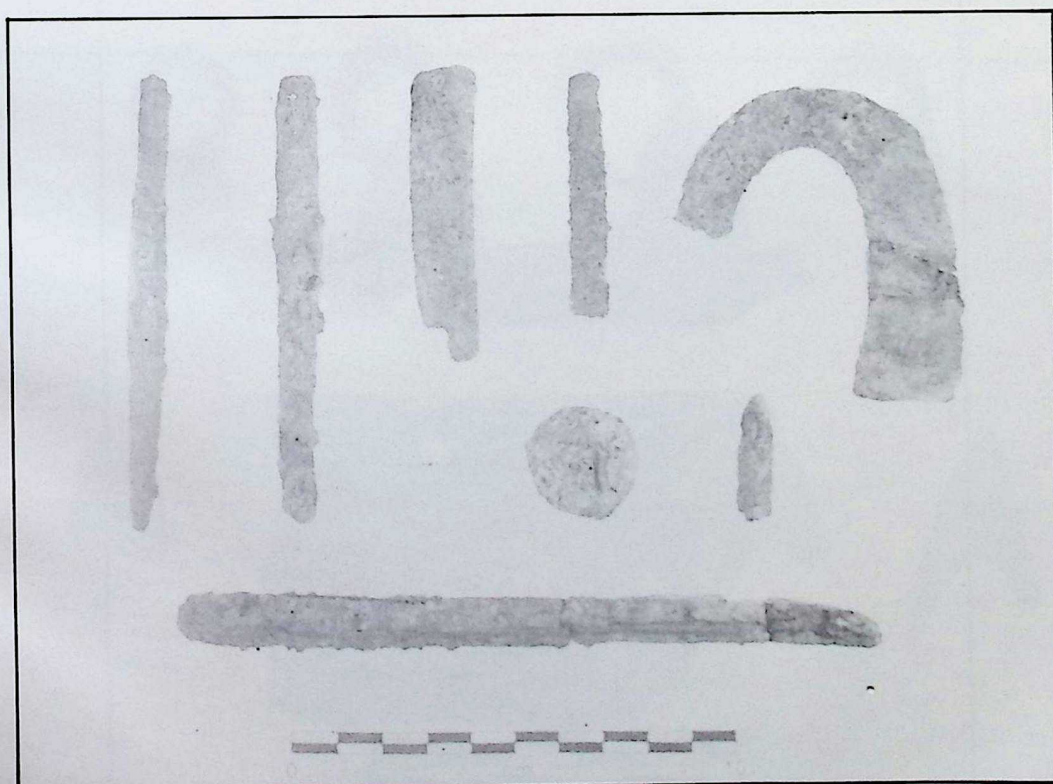


Fig. 5.25 Knife, sickle and chisel etc. from Harappa—1995 excavations.



Fig. 5.26 A horned goat head from Harappa—1995 excavations.



Fig. 5.27 Rings, knife and blade from Harappa—1995.

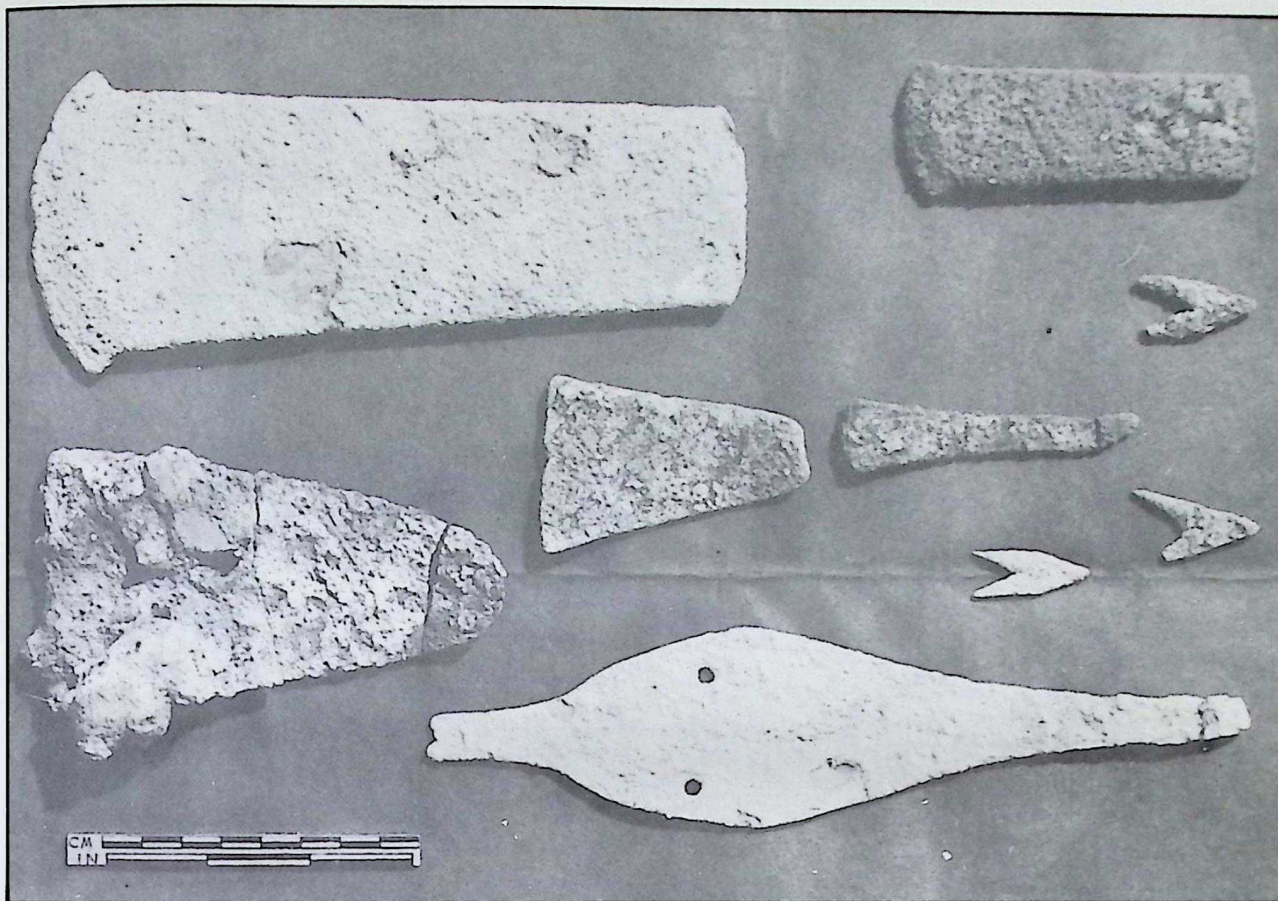


Fig. 5.28 Blade-axes, arrow-heads, splayed blade etc. from Dholavira, a Harappan site in Gujarat.



Fig. 5.29 Arrow-heads from Harappa—1995.

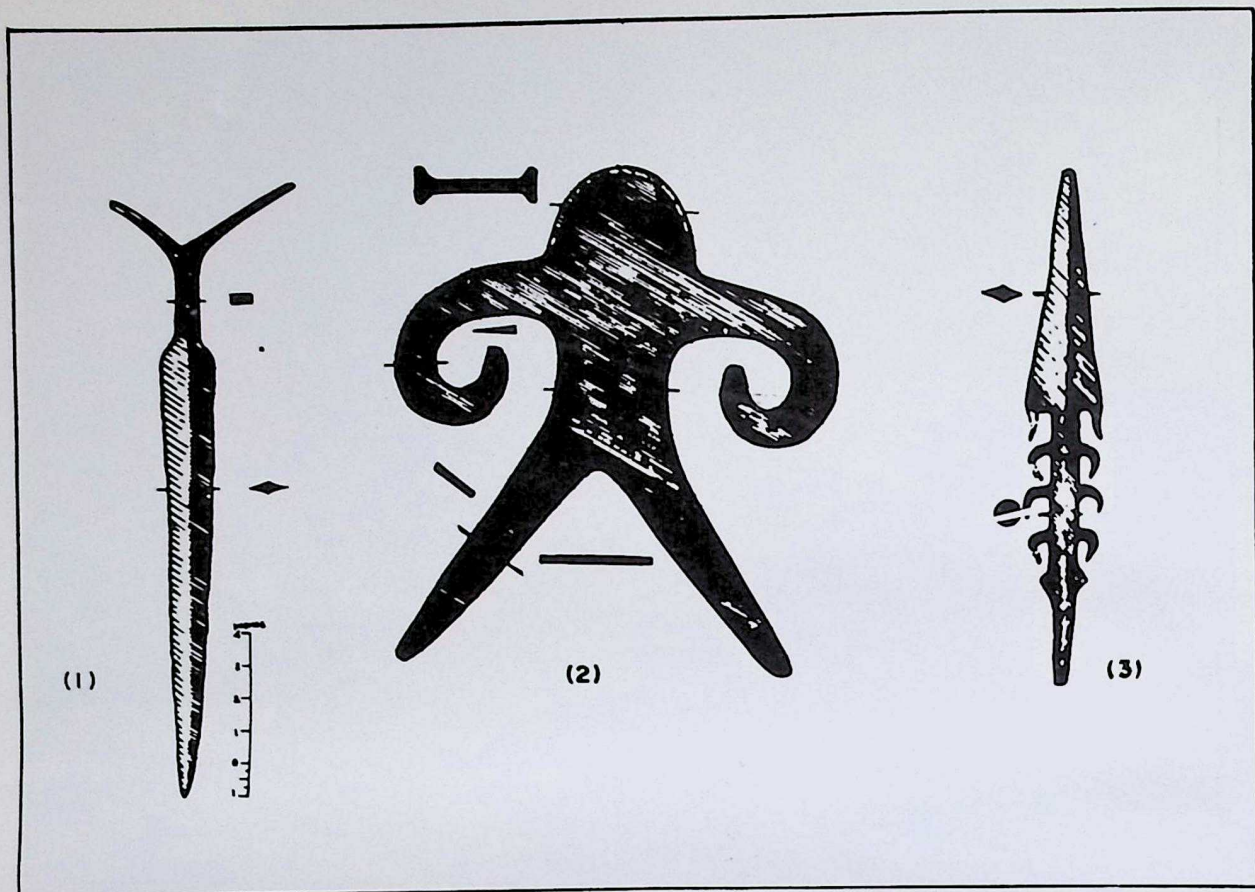


Fig. 6.1 Three most diagnostic artefact types of the Copper Hoards Culture: 1. Antennae hilted sword; 2. Anthropomorph; 3. Harpoon.

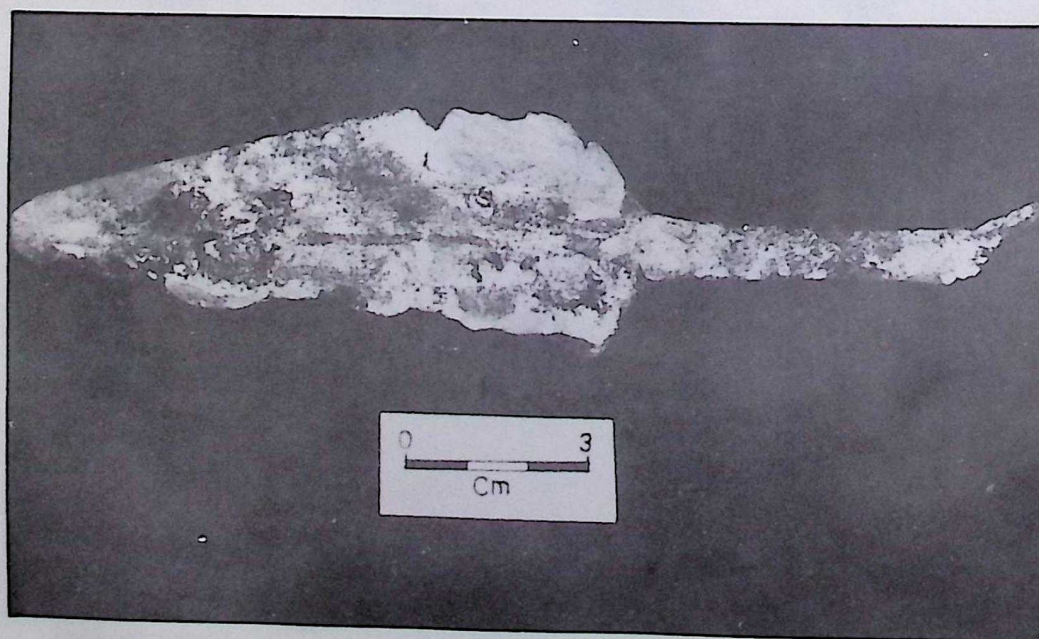


Fig. 6.2 Copper dagger with a tang, Chandoli, Maharashtra.

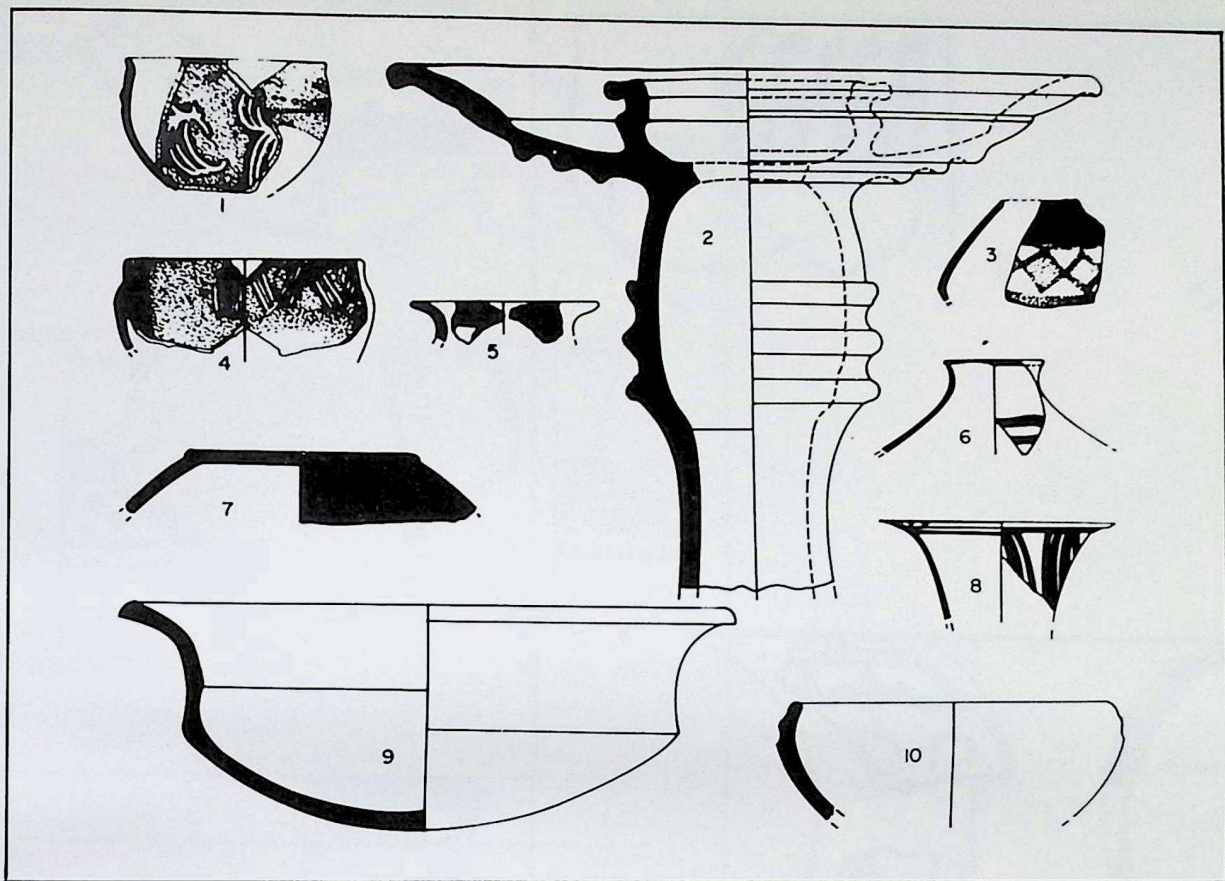


Fig. 7.1 Some Banas Ware types.



Fig. 7.2 Copper celt from Ahar, Rajasthan.



Fig. 7.3 Copper celts from Kayatha, Maharashtra, show some of the best casting techniques.

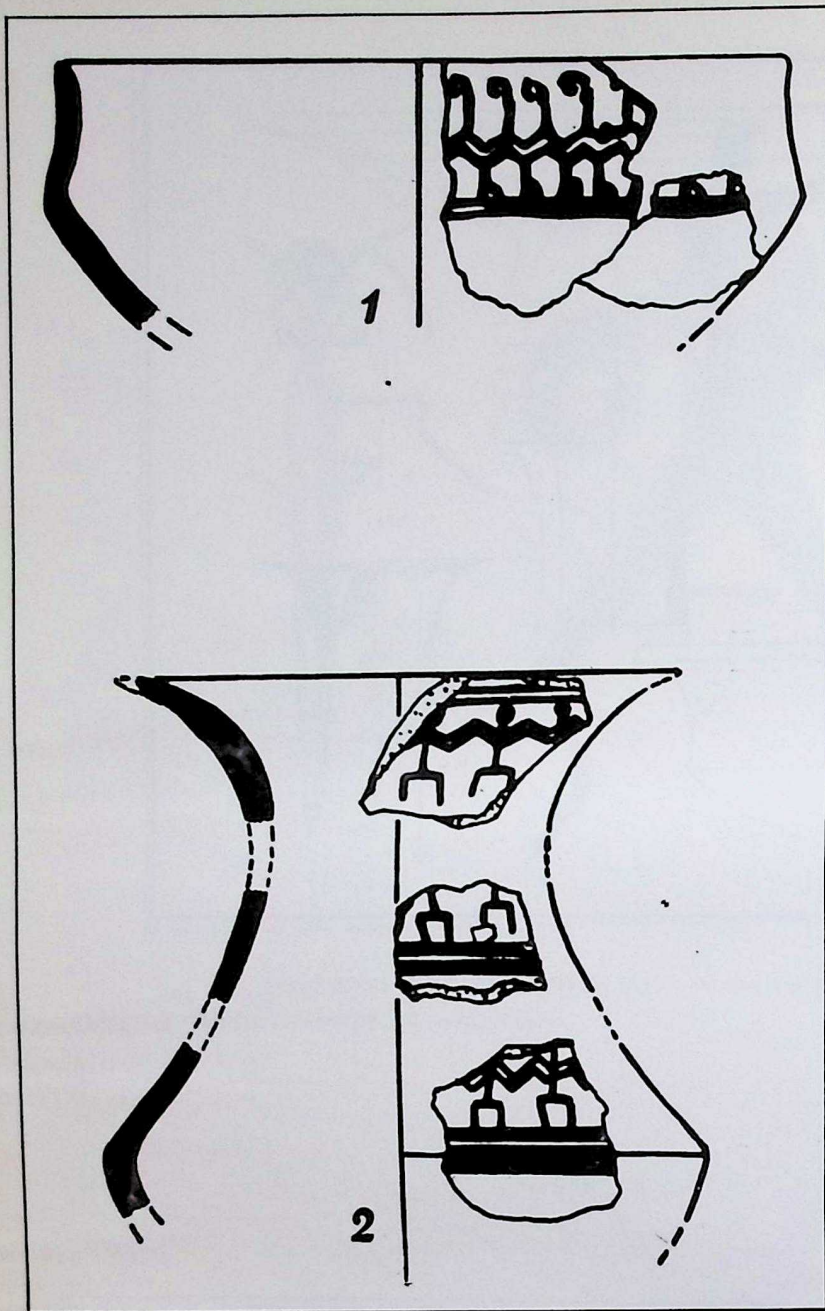


Fig. 7.4 Some Malwa Ware types.

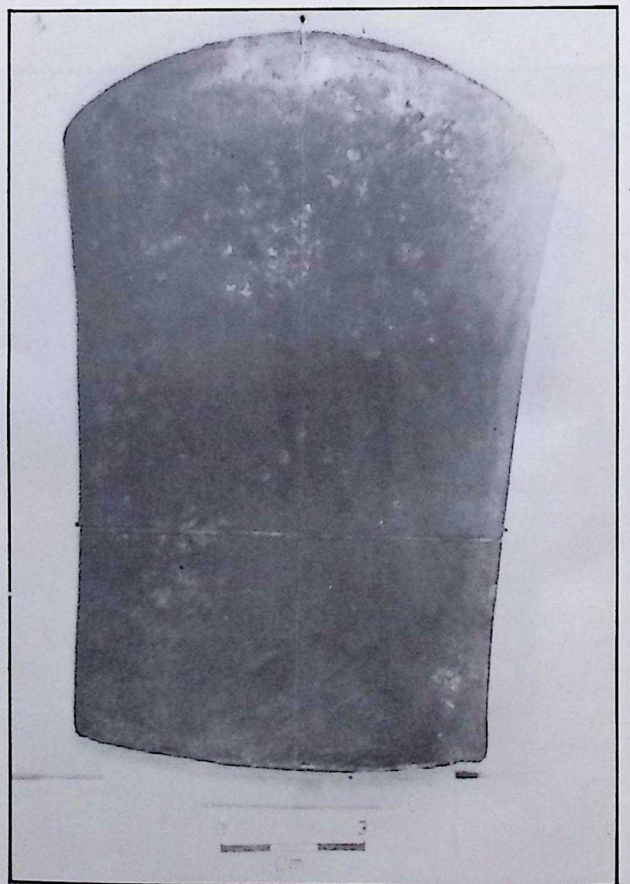


Fig. 7.5 Copper celt from Navdatoli.

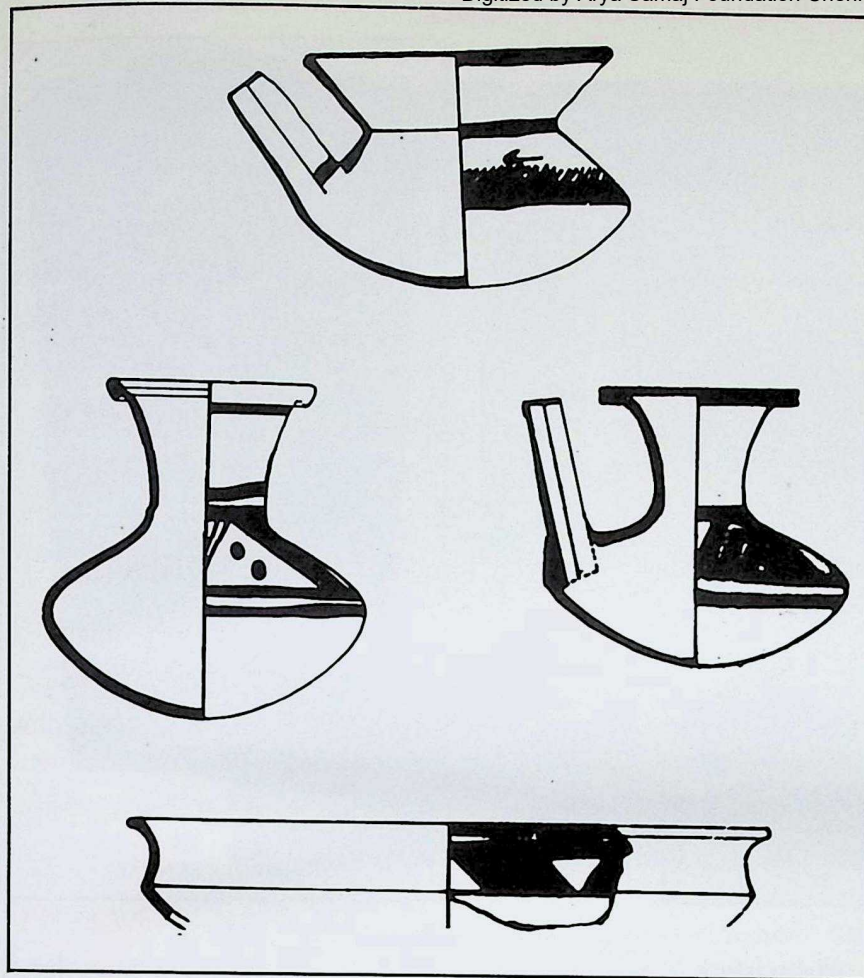


Fig. 7.6 Some Jorwe Ware types.



Fig. 7.7 A typical Jorwe spouted pot.

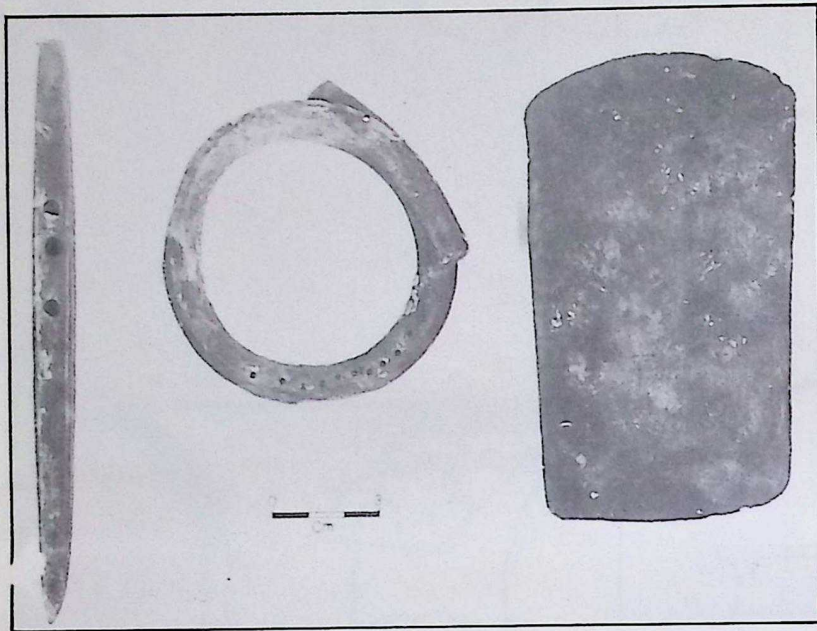


Fig. 7.8 Copper celt, chisel and ring from Nevasa, Maharashtra.

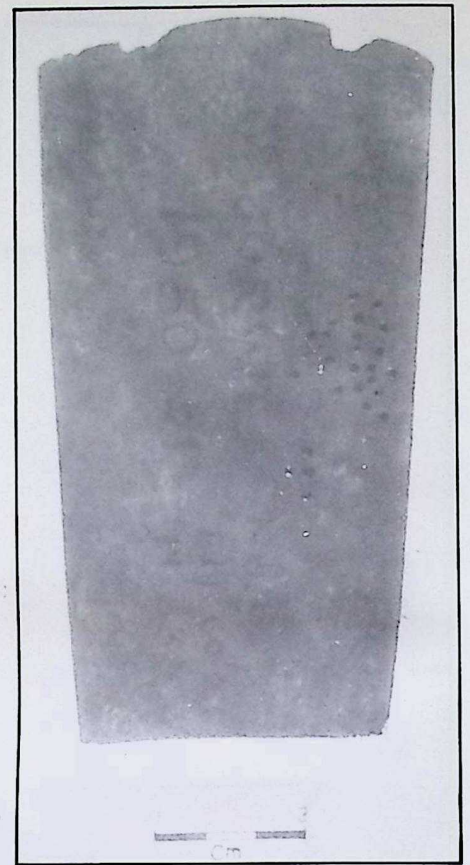


Fig. 7.9 A copper celt from Jorwe.

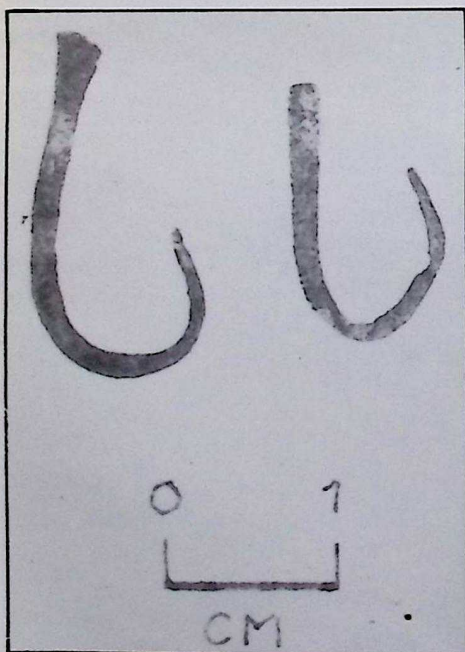


Fig. 7.10 Copper fish-hook, Inamgaon, Maharashtra.



Fig. 7.11 Copper smelting furnace from Inamgaon, Maharashtra.



Fig. 7.12 Arrow-heads and other objects from Balathal, Rajasthan.



Fig. 9.1 Socketed bronze adze (8.9 x 6.9 cm) from Early Period (mid-2nd Millennium BC) male burial. This object was neither heated nor work hardened. Banchiang (Thailand).

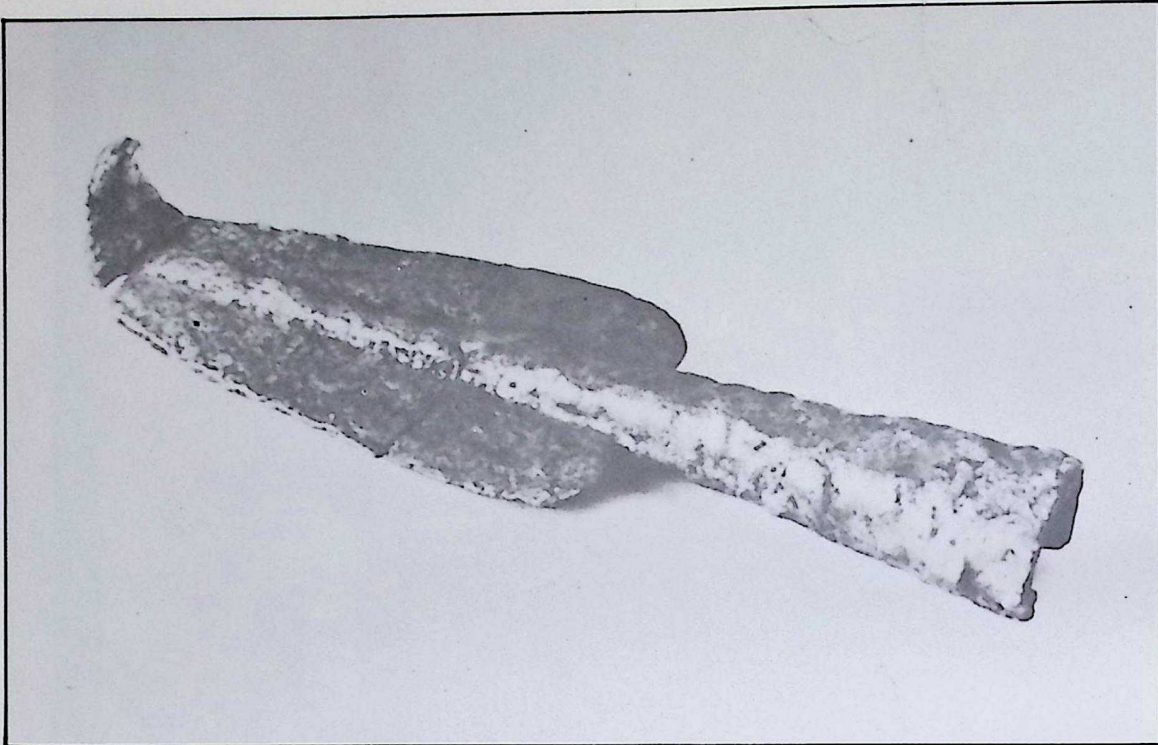


Fig. 9.2 Socketed bronze spearpoint cast in a bi-valve mould. The alloy is a low tin bronze. From a burial of Early Period (early 2nd Millennium BC). Banchiang (Thailand). Courtesy Dr. Joyce White.



Fig. 9.3 Bronze anklets (maximum diameter 6.8 cm) from a child burial (1st half of 2nd Millennium BC). Banchiang (Thailand).

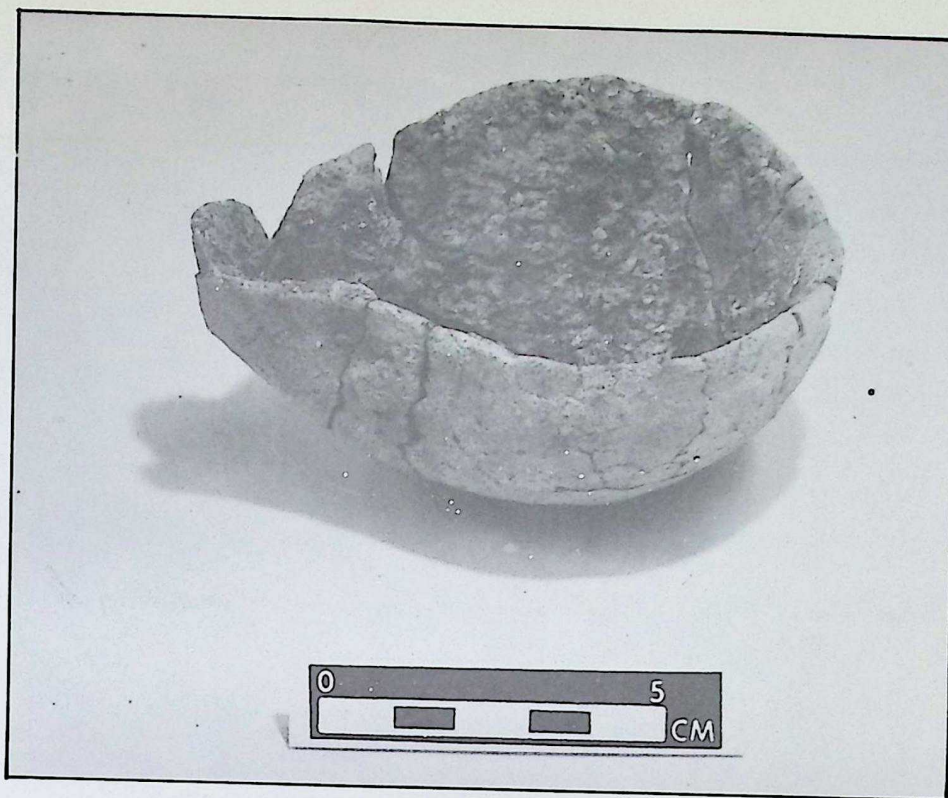


Fig. 9.4 Crucible (10.1 X 5.2 cm) from 2nd to 1st Millennium BC. Banchiang (Thailand).

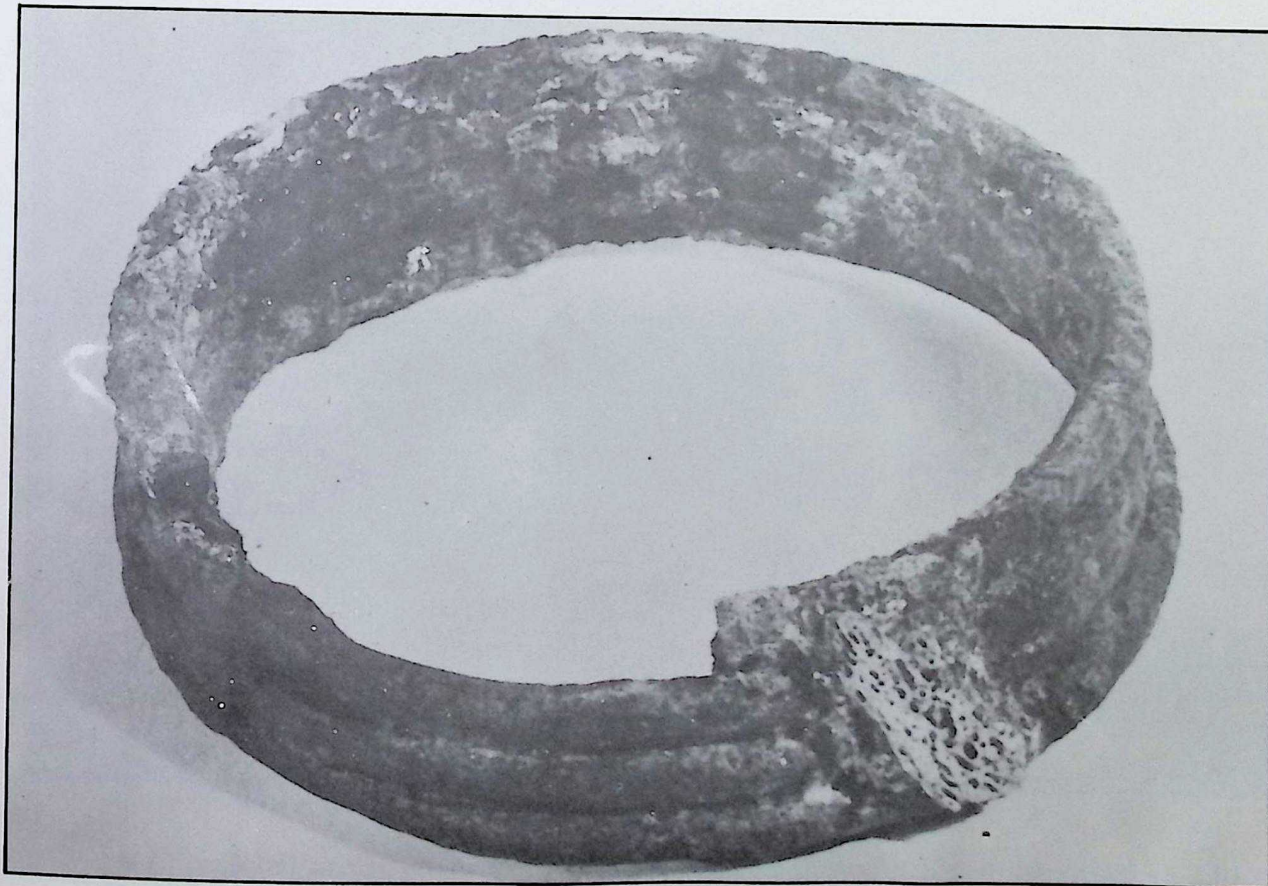


Fig. 9.5 Bronze bracelets (diameter 7.4 cm) from a male burial from Early Period (mid-2nd Millennium BC). Banchiang (Thailand).



Fig. 10.1 Bronze vessel (height 87 cm) from Zhangzhainanjie, Zhenzhou, Henan Province, China. Period 1600-1100 BC.

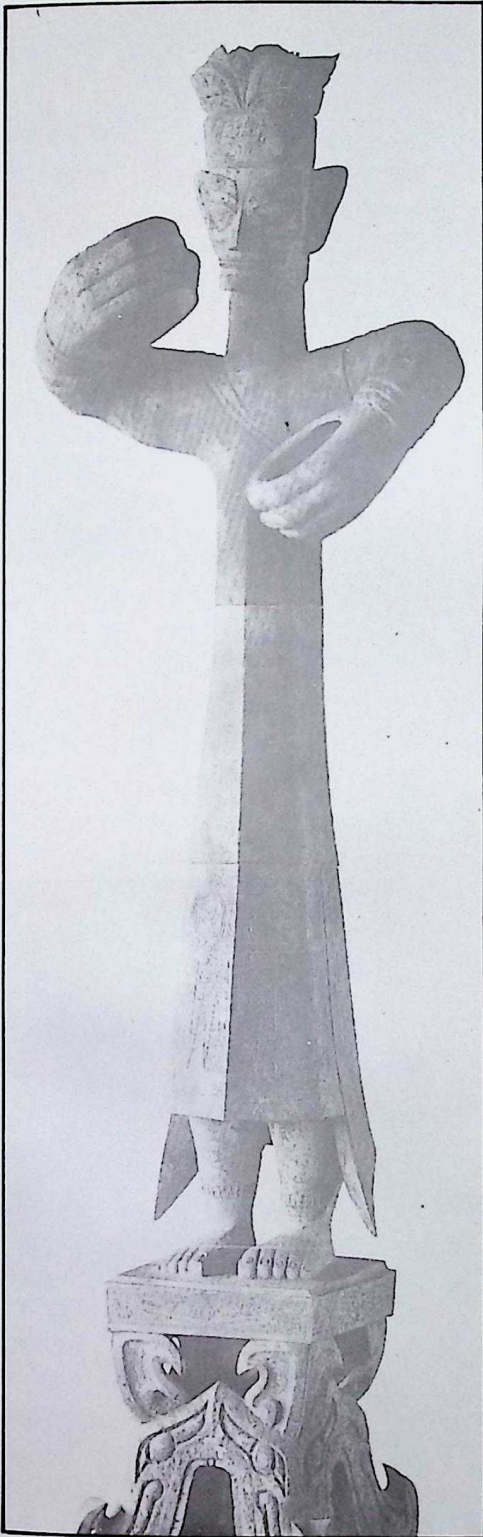


Fig. 10.2 Human figure (height 262 cm) from Sanxingdui, China. Period 1400-1100 BC.

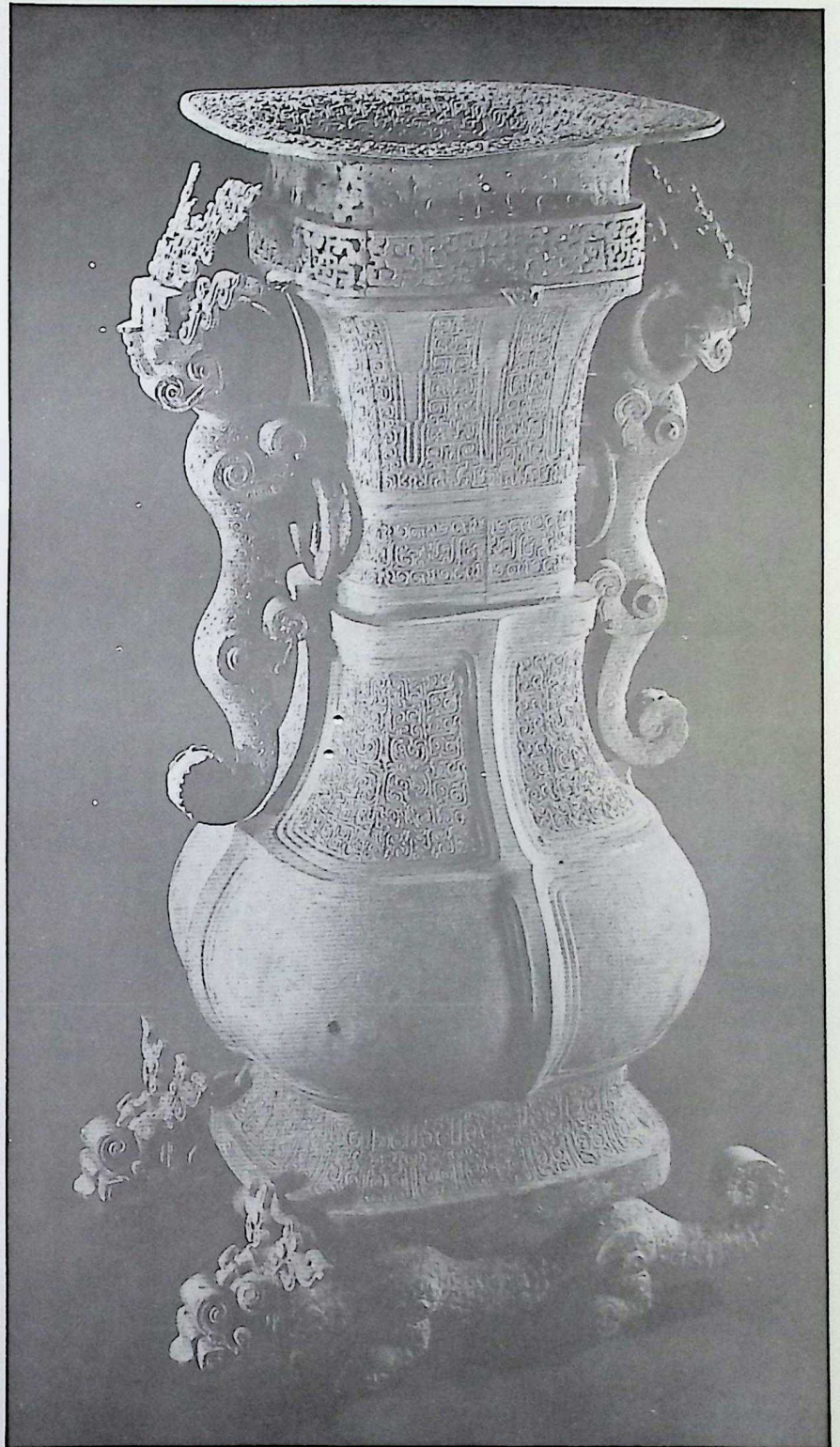


Fig. 10.3 Bronze vessel (Height 79.2 cm) from Tomb No.1, Xiasi, Xichuan County, Henan, China. Period 770-476 BC.



Fig. 10.4 Bronze vessel (46 cm height), from Fuhao Mu (tomb), Anyang, Henan, China. Period 1600-1400 BC.

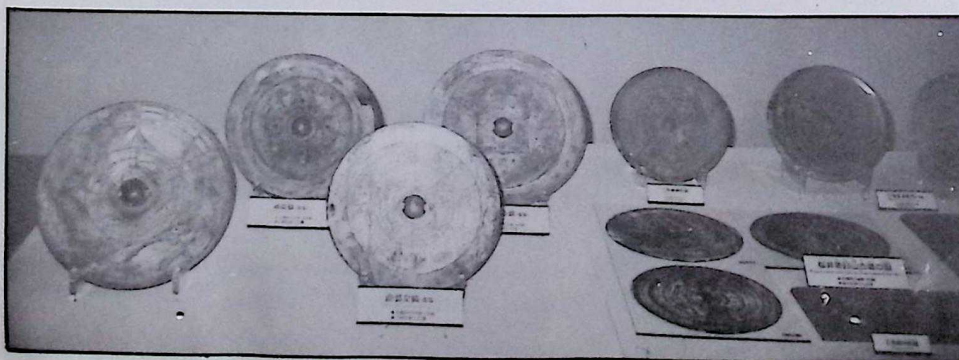


Fig. 10.5 Bronze mirrors from Nara Prefecture (Japan). Front two mirrors are made in Japan; the others made in China. c. 4th century AD.



Fig. 10.6 Bronze mirror from Niizawa (No. 109 Tomb), Nara Prefecture (Japan).



Fig. 10.7 Dotaku (bell) from Hatsu Kayama site, Late Yayoi Period, second century AD. Nara Prefecture (Japan).

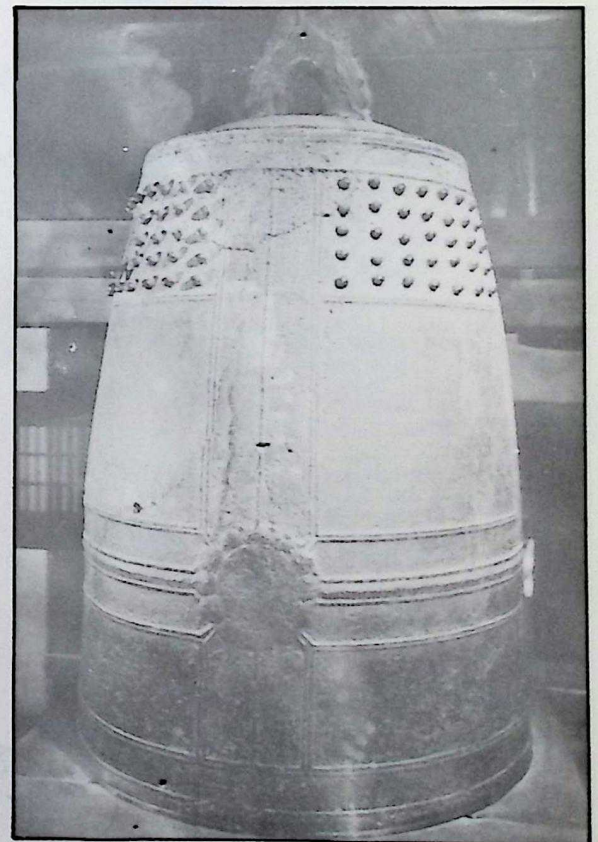


Fig. 10.8 Bronze bell from Otsu (Japan). Early c. 8th century AD.

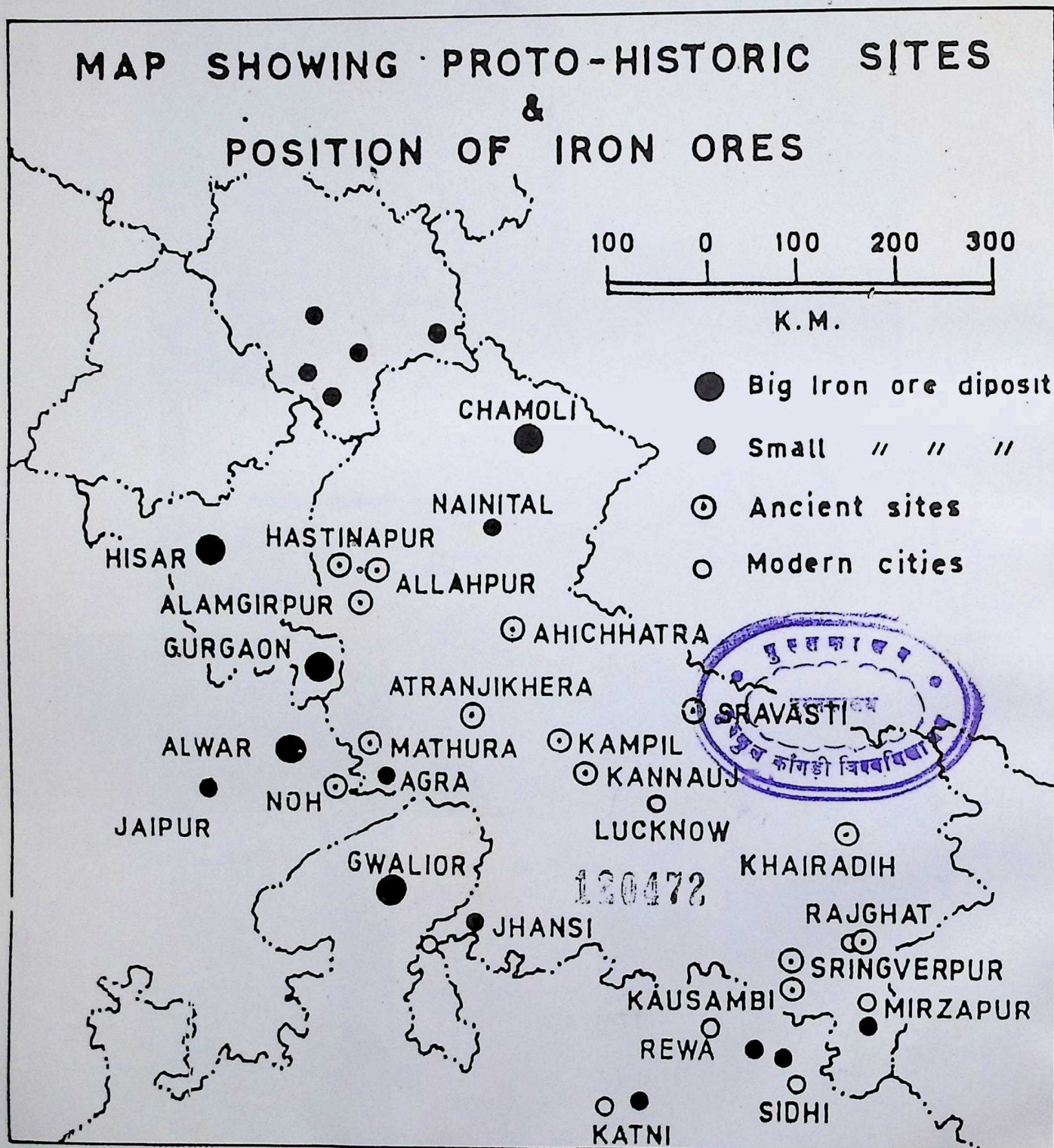
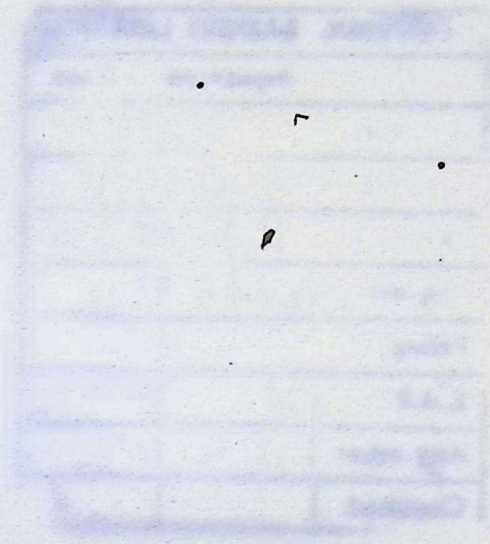


Fig. 11.1 Map showing proto-historic sites and iron ore mines in north India.



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In the course of his long academic career, Prof. D.P. Agrawal has worked with the Archaeological Survey of India, Tata Institute of Fundamental Research, Bombay and Physical Research Laboratory (PRL), Ahmedabad. His research contributions have been varied and multi-disciplinary – mainly in the fields of archaeology, radiocarbon & TL dating, archaeometallurgy, and palaeoenvironment. Prof. Agrawal has done extensive work on archaeometallurgy of the Harappa Culture, the Copper Hoards Culture, and also in the Central Himalayan region. Prof. Agrawal has specialised in the use of scientific techniques for archaeological research. He has also made fundamental theoretical contributions in the fields of language and evolution, flaking mechanics, archaeological theories and concepts of time. He retired as a senior professor and chairman of a large multi-disciplinary group at Physical Research Laboratory. He has organised and attended numerous national and international symposia. He has given invited talks at the leading centres of archaeological and palaeoenvironmental research both in India and abroad. He has been a visiting professor at the University of Pennsylvania and International Research Centre at Kyoto for a year each. He has published 14 books and about 250 papers. He is a member of the advisory boards of *World Archaeology*, *Le'Anthropologie* and has edited *Man & Environment* for a number of years. He has been the Chairman of Indian Society for Prehistoric and Quaternary Research, member of the Central Advisory Board of Archaeology, and has been associated with several other academic committees—both national and international. He is a Fellow of the Indian Academy of Science.



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